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On the Sensitivity of the Daily Maximum and Minimum Air Temperature of Egypt to Soil Moisture Status and Land Surface Parameterization Using the RegCM4

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Motivation

- The present study aims to:

  1. Examine the sensitivity of the daily maximum (TMX) and minimum air temperature (TMN) of Egypt to the status of the soil moisture initialization (bare soil versus ESACCI global satellite soil moisture product) using the RegCM4.

  2. Study the role of land surface parameterization (BATS and CLM45) in simulating the daily TMX and TMN of Egypt with respect to the Climate Research Unit (CRU) considering the ESACCI as the initial condition of the soil moisture.

  3. Evaluate the climatological annual cycle of the TMX and TMN with respect to the station observations.

Experiment Design

- To address the purpose of the present study, four 13-year simulations (1998 – 2010) were conducted. The four simulations were divided to two groups.
- The first group considered the sensitivity of the TMX and TMN to the status of the initialized soil moisture either from the bare soil or from the ESACCI satellite soil moisture product.
- The second group discusses the sensitivity of the simulated TMX/TMN to land surface parameterization (BATS and CLM45).
- In the four simulations, the first three years were considered as a spin-up so the simulated soil moisture can approach an equilibrium state following (Steiner et al. 2009).

Figures

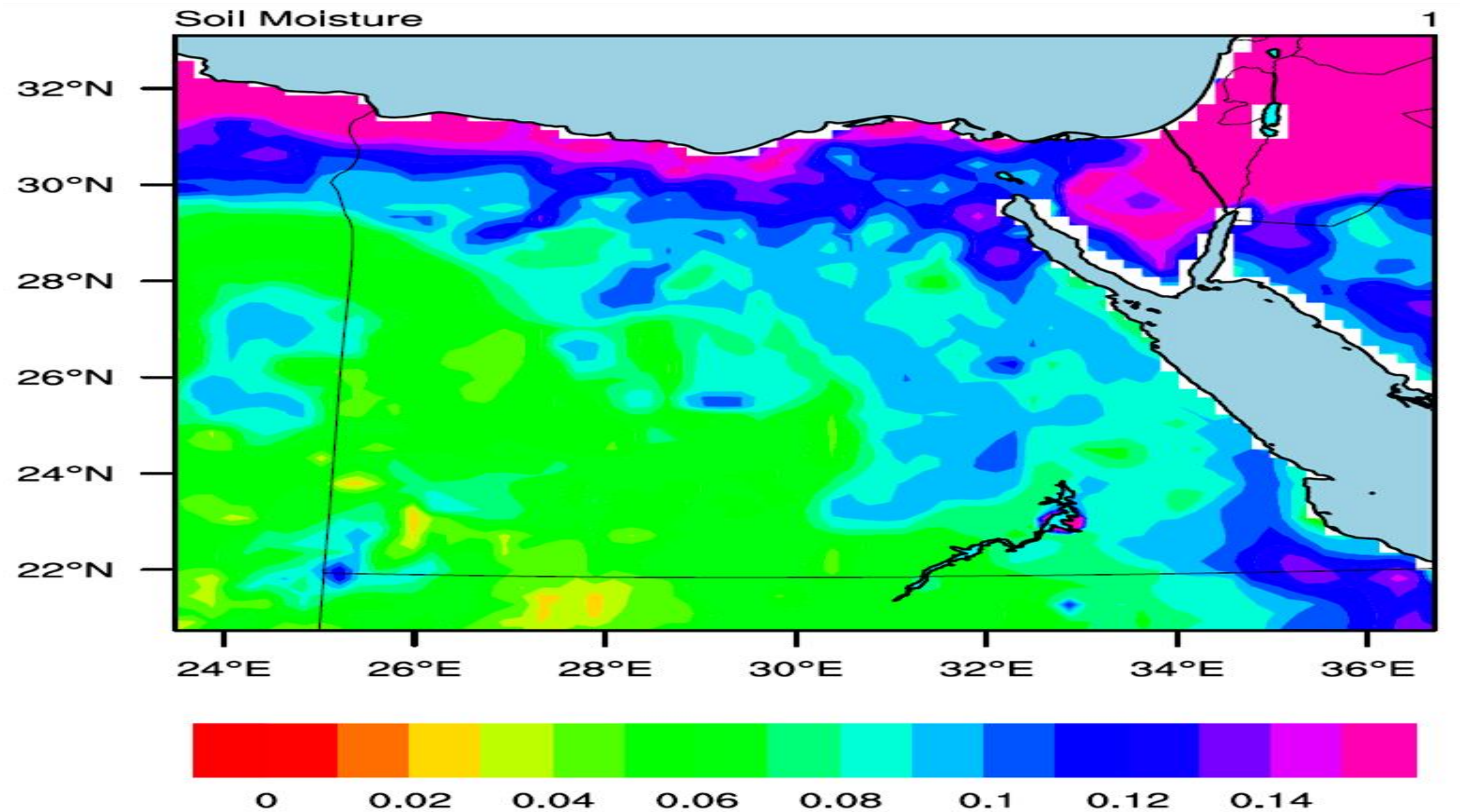


Figure 1. The figure shows the interpolated ESACCI satellite soil moisture product on the RegCM4 curvilinear grid.

Soil Moisture Initialization

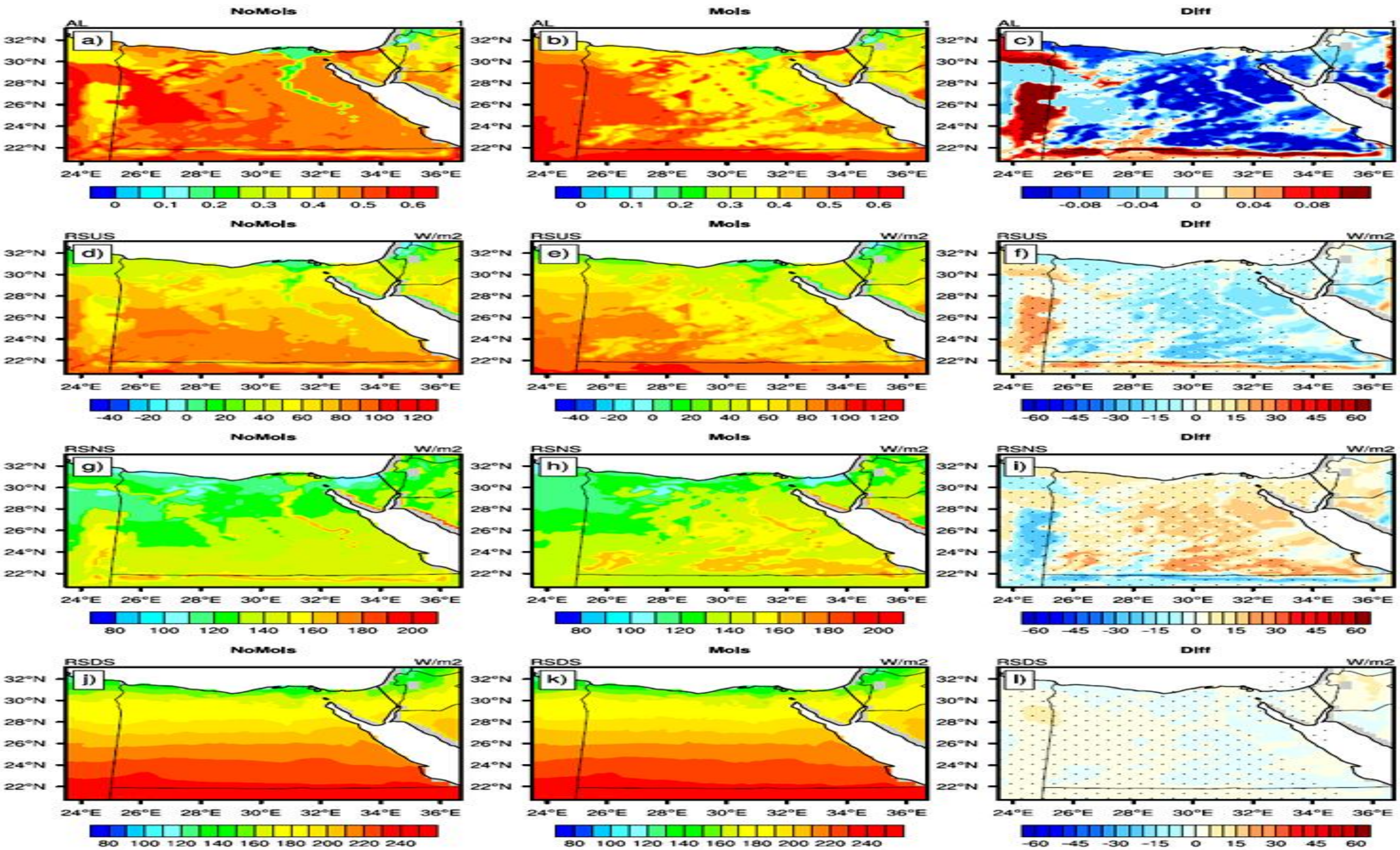


Figure 2. The figure shows the comparison between NoMois and Mois for the variables: 1 – total albedo (Al; Figure 2 a – c), 2 – surface upward short wave radiation (RSUS; Figure 2 d – f), 3 – surface net short wave radiation (RSNS; Figure 2 g – i) and 4 – downward short wave radiation (RSDS; Figure 2 j – l).

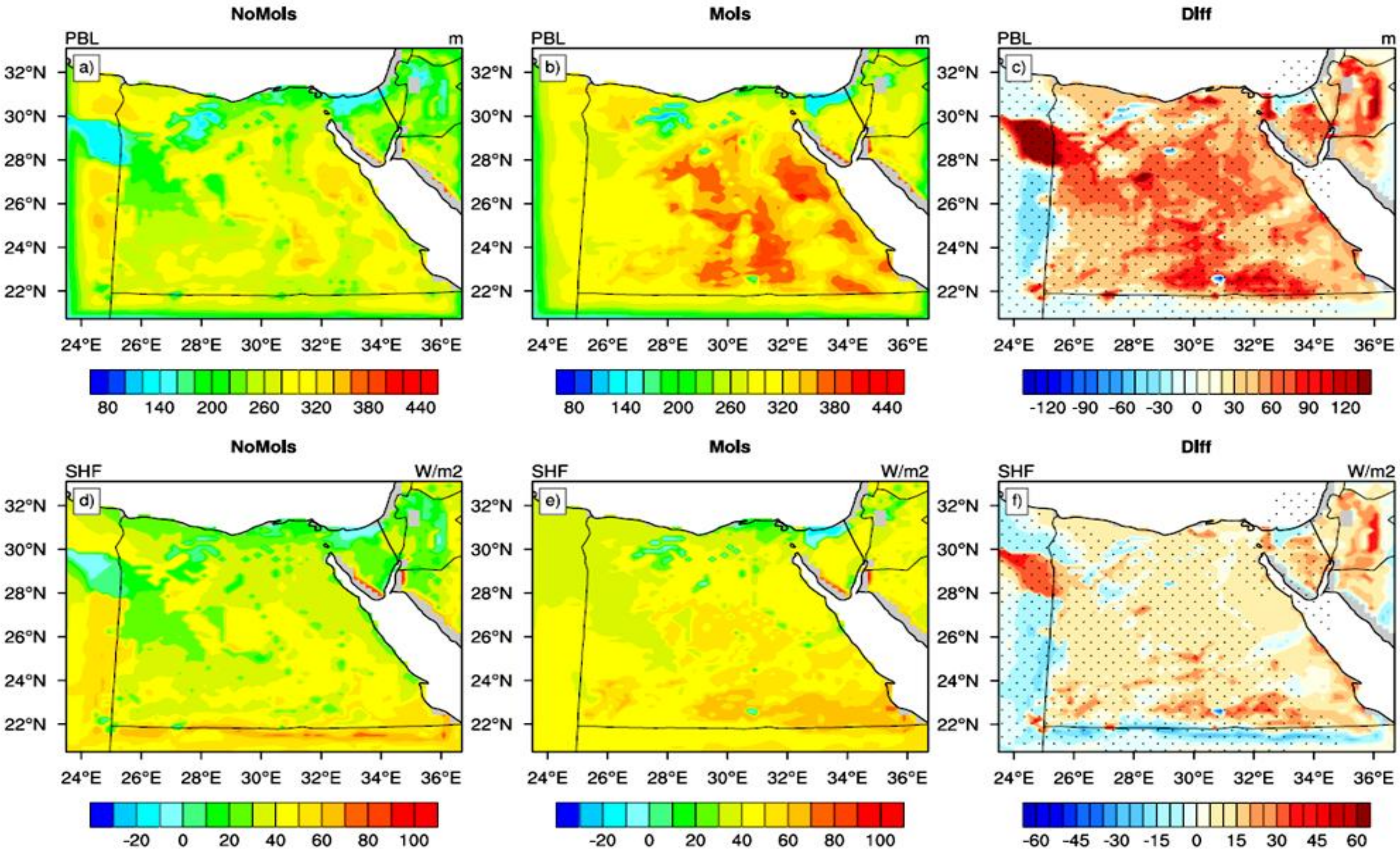


Figure 3. The figure shows the comparison between NoMois and Mois for the variables: 1 – planetary boundary layer height (PBL; Figure 3 a – c) and 2 – surface sensible heat flux (SHF; Figure 3 d – f).

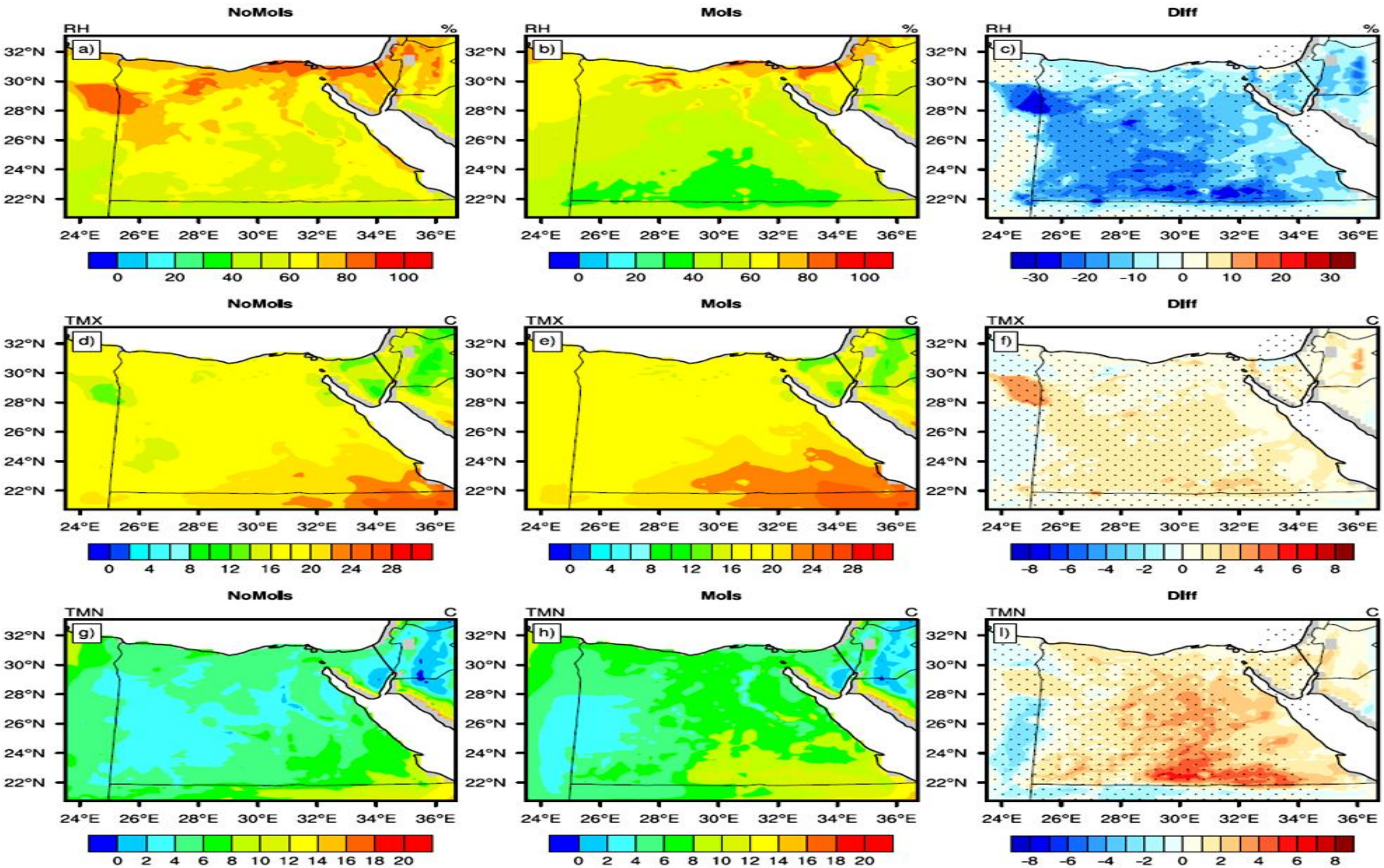


Figure 4. The figure shows the comparison between NoMois and Mois for the variables: 1 – near surface relative humidity (RH; Figure 4 a – c), 2 – near surface maximum air temperature (TMX; Figure 4 d – f) and 3 – near surface minimum air temperature (TMN; Figure 4 g – i).

Land Surface Parameterization

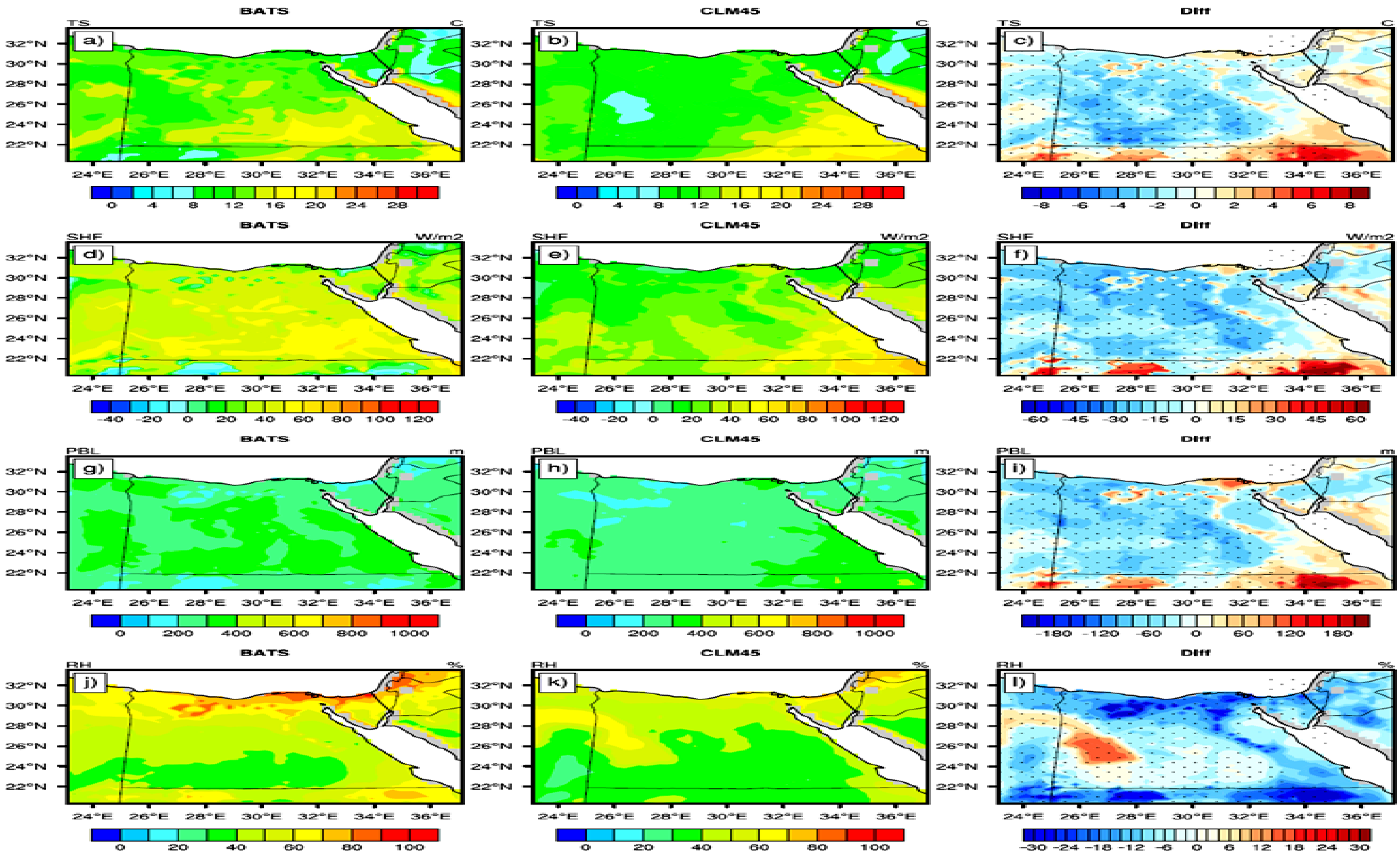


Figure 5. The figure shows the comparison between BATS and CLM45 land surface schemes for the variables: 1 – ground temperature (TS; Figure 5 a – c), 2 – sensible heat flux (SHF; Figure 5 d – f), 3 – planetary boundary layer height (PBL; Figure 5 g – i) and 4 – near surface relative humidity (RH; Figure 5 j – l).

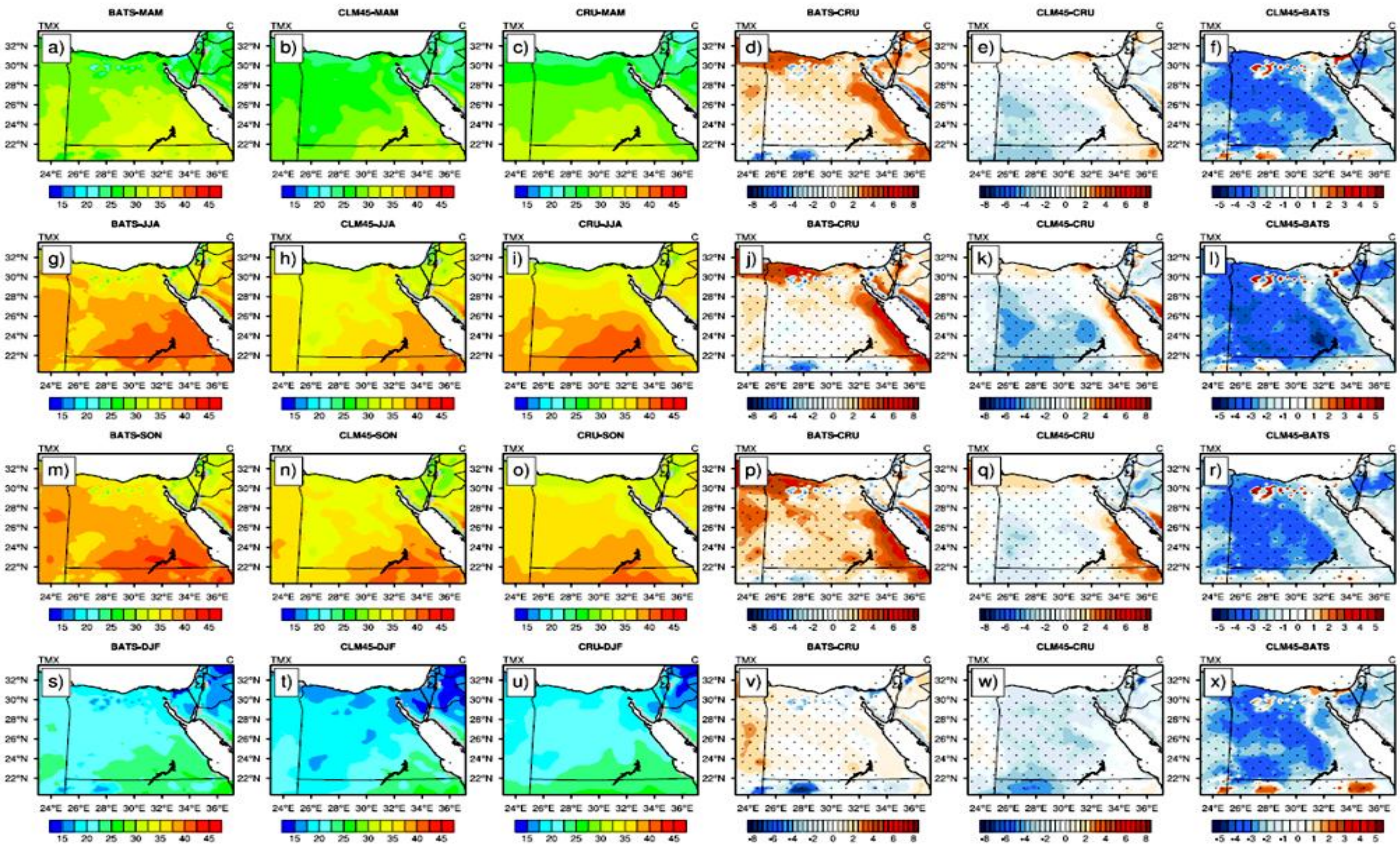


Figure 6. The figure shows the simulated daily maximum air temperature over the period 2001–2010 (TMX; in °C) for the seasons: MAM in the first row (a-f); JJA in the second (g-l); SON in the third (m-r), DJF in the fourth (s-x). For each row, BATS is on the left, followed by CLM45. CRU is in the third from left, BATS minus CRU, CLM45 minus CRU and the difference between CLM45 and BATS. Significant difference/bias is indicated in black dots using student t-test with alpha equals to 5%

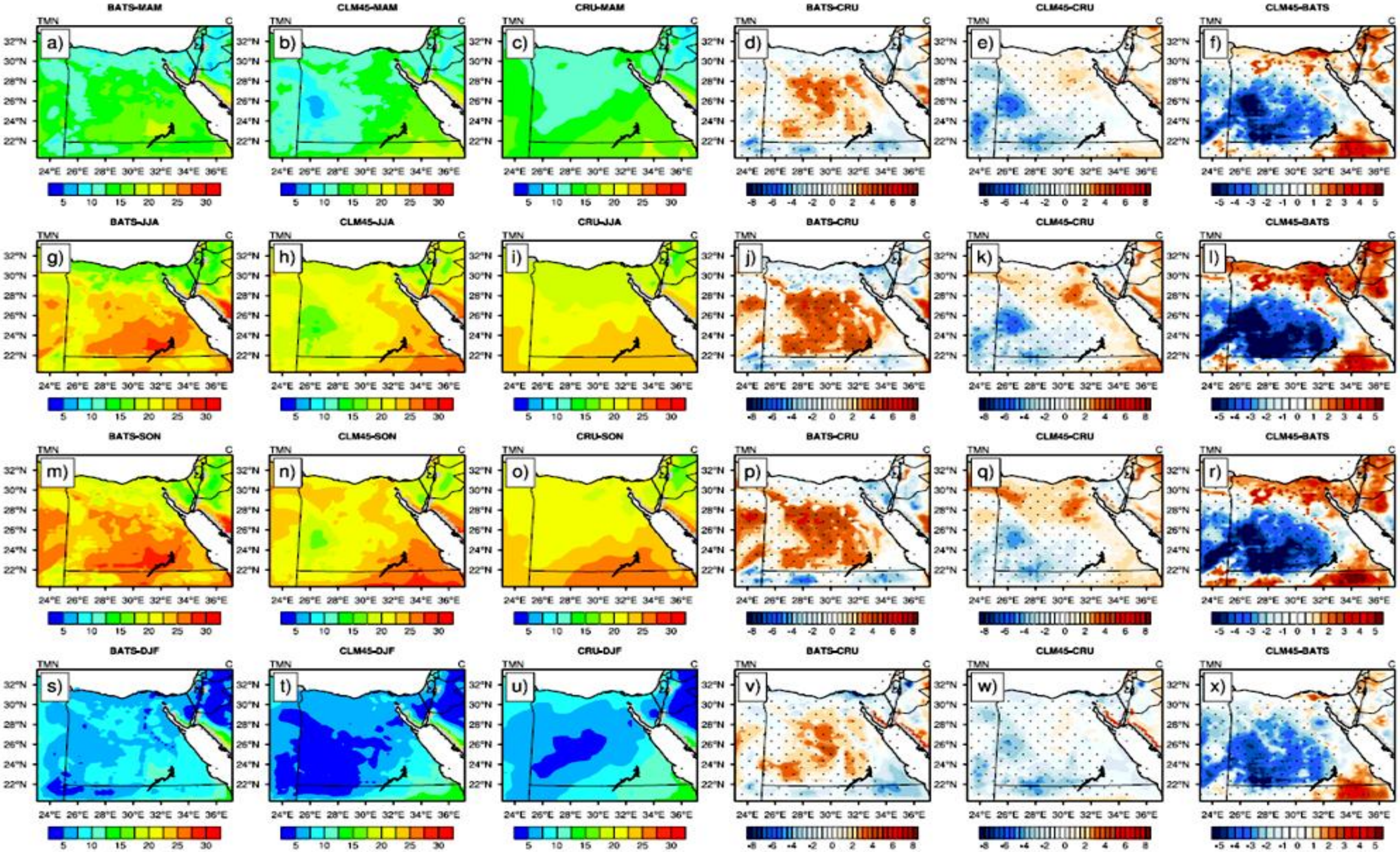
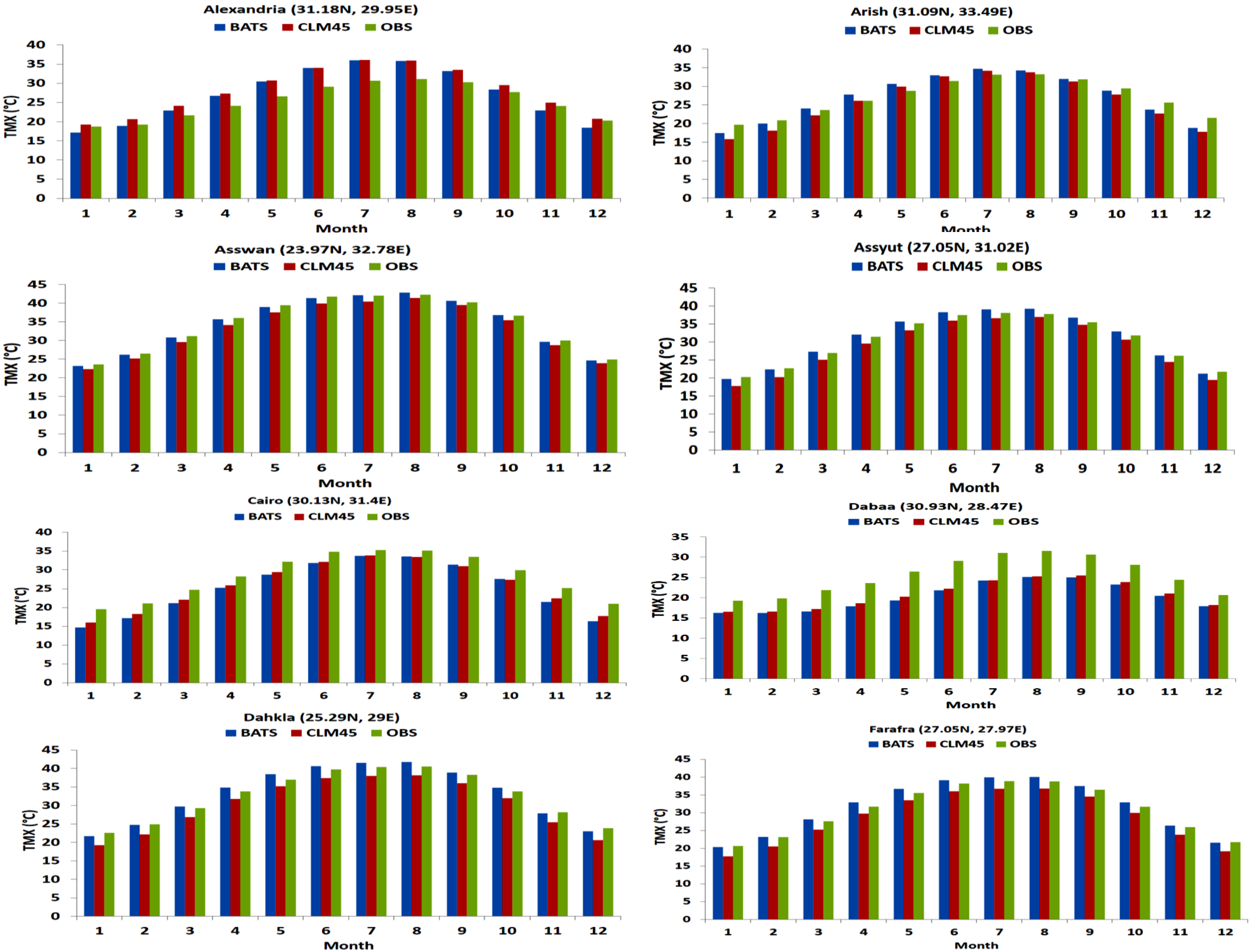


Figure 7. The figure shows the simulated daily minimum air temperature over the period 2001–2010 (TMN; in °C) for the seasons: MAM in the first row (a-f); JJA in the second (g-l); SON in the third (m-r), DJF in the fourth (s-x). For each row, BATS is on the left, followed by CLM45. CRU is in the third from left, BATS minus CRU, CLM45 minus CRU and the difference between CLM45 and BATS. Significant difference/bias is indicated in black dots using student t-test with alpha equals to 5%



Alexandria (31.18N, 29.95E)
BATS
CLM45
OBS
TMX (°C)
Month
Arish (31.09N, 33.49E)
BATS
CLM45
OBS
TMX (°C)
Month
Asswan (23.97N, 32.78E)
BATS
CLM45
OBS
TMX (°C)
Month
Assyut (27.05N, 31.02E)
BATS
CLM45
OBS
TMX (°C)
Month
Cairo (30.13N, 31.4E)
BATS
CLM45
OBS
TMX (°C)
Dabaa (30.93N, 28.47E)
BATS
CLM45
OBS
TMX (°C)
Month
Dahkla (25.29N, 29E)
BATS
CLM45
OBS
TMX (°C)
Month
Farafra (27.05N, 27.97E)
BATS
CLM45
OBS
TMX (°C)
Month

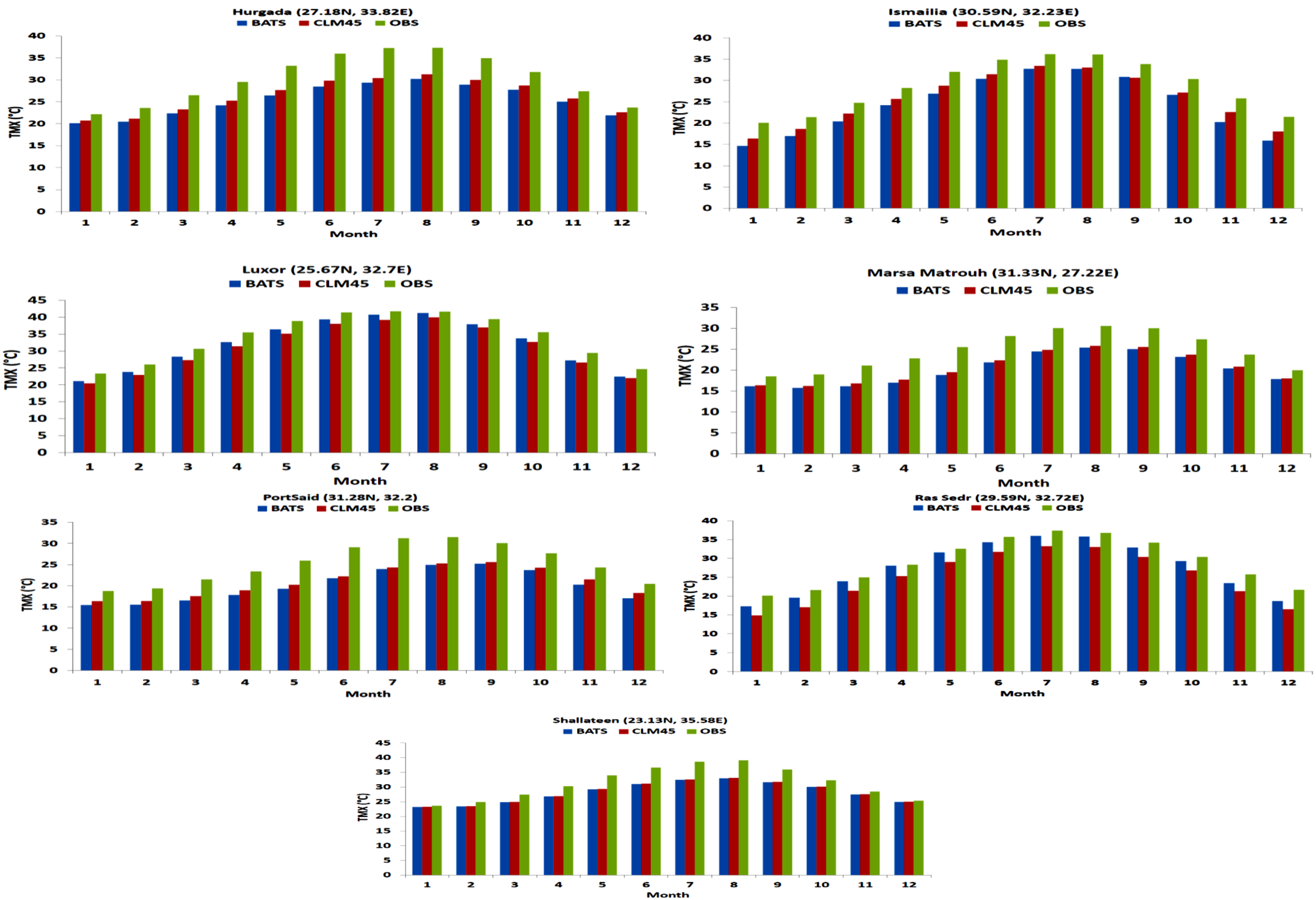
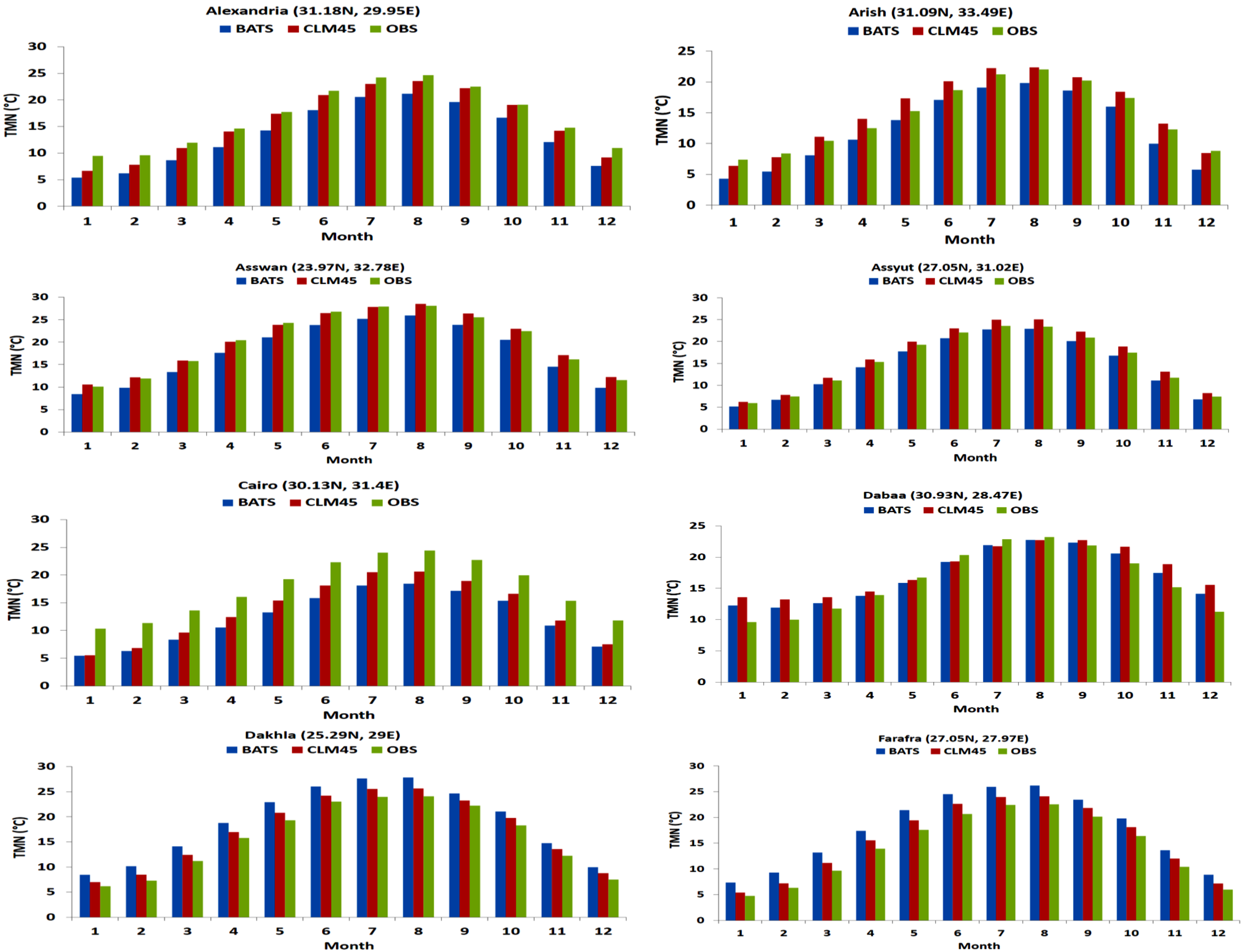


Figure 8. The figure shows the climatological annual cycle of the daily maximum air temperature over the period 2001–2010 (TMX; in °C) for the fifteen locations indicated in table 1. BATS scheme appears in blue color, CLM45 scheme in red color and station observation (OBS) in green color.



Alexandria (31.18N, 29.95E)
BATS CLM45 OBS
TMN (°C)
0 5 10 15 20 25 30
1 2 3 4 5 6 7 8 9 10 11 12
Month
Arish (31.09N, 33.49E)
BATS CLM45 OBS
TMN (°C)
0 5 10 15 20 25
1 2 3 4 5 6 7 8 9 10 11 12
Month
Asswan (23.97N, 32.78E)
BATS CLM45 OBS
TMN (°C)
0 5 10 15 20 25 30
1 2 3 4 5 6 7 8 9 10 11 12
Month
Assyut (27.05N, 31.02E)
BATS CLM45 OBS
TMN (°C)
0 5 10 15 20 25 30
1 2 3 4 5 6 7 8 9 10 11 12
Month
Cairo (30.13N, 31.4E)
BATS CLM45 OBS
TMN (°C)
0 5 10 15 20 25 30
1 2 3 4 5 6 7 8 9 10 11 12
Month
Dabaa (30.93N, 28.47E)
BATS CLM45 OBS
TMN (°C)
0 5 10 15 20 25
1 2 3 4 5 6 7 8 9 10 11 12
Month
Dakhla (25.29N, 29E)
BATS CLM45 OBS
TMN (°C)
0 5 10 15 20 25 30
1 2 3 4 5 6 7 8 9 10 11 12
Month
Farafra (27.05N, 27.97E)
BATS CLM45 OBS
TMN (°C)
0 5 10 15 20 25 30
1 2 3 4 5 6 7 8 9 10 11 12
Month

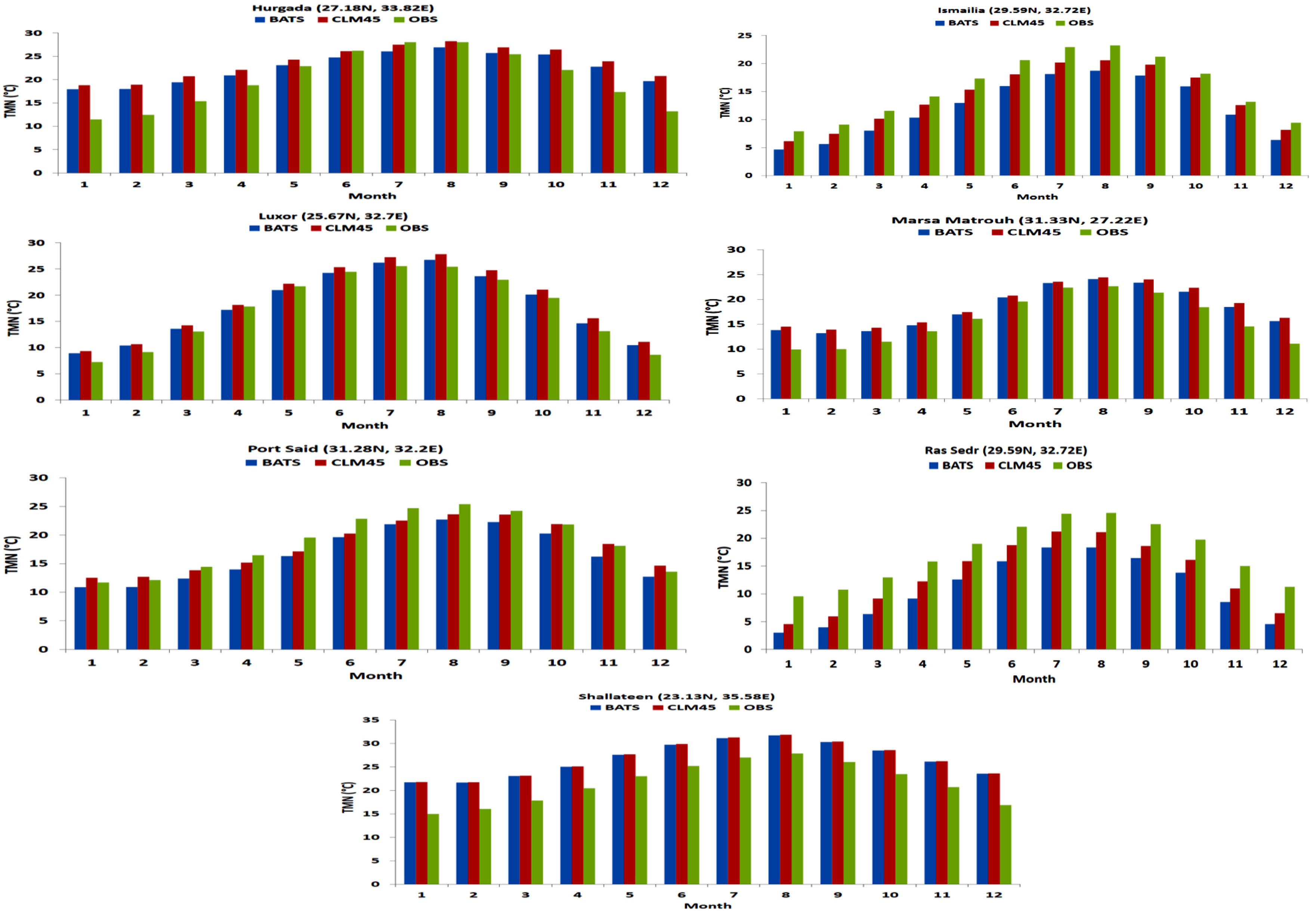


Figure 9. The figure shows the climatological annual cycle of the daily minimum air temperature over the period 2001–2010 (TMN; in °C) for the fifteen locations indicated in table 1. BATS scheme appears in blue color, CLM45 scheme in red color and station observation (OBS) in green color.

Discussion

- In the present study, the RegCM4 regional climate model was used to examine the sensitivity of the simulated TMX/TMN of Egypt to different initial conditions of the soil moisture (bare soil against the ESACCI satellite soil moisture product).
- The results showed that switching from the bare soil to the ESACCI satellite product induces a considerable influence on the simulated TMX/TMN through changes in the total albedo, solar radiation budget, planetary boundary layer height, sensible heat flux and near surface relative humidity.
- Switching from BATS to CLM45 led to decrease of the ground temperature, sensible heat flux, planetary boundary layer height and near surface relative humidity. As a result, heat flow (from the earth surface to the adjacent atmosphere layer and eventually to the whole planetary boundary layer) decreased.
- Such behavior can explain the warm (cold) bias of the BATS (CLM45) with respect to the CRU.
- Despite of the noted biases, the CLM45 succeeded in reducing the observed warm bias of the BATS. Compared to the OBS, behavior of the BATS/CLM45 varies with the location of interest concerning the TMX. For the TMN, the CLM45 outperforms the BATS in majority of locations as can be noted in Figure 9.

Conclusion

- The RegCM4 regional climate model can be recommended for future studies concerning climate change of the daily TMX/TMN and temperature indices of Egypt (under different warming scenarios) when it is configured with the CLM45 land surface model and initialized with the ESACCI satellite soil moisture product.
- In comparison with the OBS, caution must be taken in selecting the suitable scheme in the location of study.
- Given the observed effects (by switching from bare soil to ESACCI satellite product and land surface parameterization), it is recommended to investigate such effects in other arid regions to ensure an optimized performance of the RegCM4 with respect to reanalysis products and station observations.
- In a future work, the following points need to be addressed: 1 - Running the RegCM in a convective permitting scale and a parameterized convective schemes following Giorgi et al. (2023), 2 - revising the results reported by Anwar et al. (2022) and Ali et al. (2023) when the RegCM4 is configured with the CLM45 land surface model and initialized with the ESACCI product and 3 - Assessing the diurnal and daily variations of the RegCM4-CLM45 regional coupled climate model with the results reported by Frey et al. (2011).