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Modeling the future scenarios for surface temperature and wind regime over the South-Eastern Levantine Basin, Egypt

Mohamed Elbessa [1,3], Saad Mesbah Abdelrahman [2], Kareem Tonbol [2] and Mohamed Shaltout [3,*]

1. Maritime Postgraduate Studies Institute (MPI), Arab Academy for Science, Technology and Maritime Transport (AASTMT), Abu-Qir, Alexandria 1029, Egypt.
2. College of Maritime Transport and Technology, Arab Academy for Science, Technology and Maritime Transport, Alexandria 1209, Egypt.
3. Oceanography Department, Faculty of Science, Alexandria Univ., Alexandria 21526, Egypt:

*** Correspondence Author: mohamed.shaltot@alexu.edu.eg**

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ABSTRACT

The understanding of long-term variabilities for surface air temperature and the wind regime is essential for the adaptation and mitigation plans over South Eastern Levantine (SEL), the current paper analyses the recent trends of Sea Surface Wind (SW), and surface air temperature (T2m) using regional climate model of RegCM-SVN from 2006 up to 2100 with 25 km^2 grid resolution. RegCM-SVN was driven with ERA5 for recent simulations (2006-2020). However, the model was driven with two Coupled Model Intercomparison Project Phase 5 (CMIP5) scenarios (i.e. RCP2.6 and RCP 8.5)) RCP 2.6 and RCP 8.5 scenarios of HADGEM for future simulations (2006-2100). The bias between the simulated results and ERA5 reanalysis data was used to assess the modeling results along the Mediterranean Sea. Moreover, ERA5 database was used to understand the model simulations of T2m and WS over SEL. The results proved that RegCM-SVN in the future simulation (2020-2100) for T2m, U_{10} and V_{10} using two climate change scenarios; RCP 2.6 and RCP8.5 over the SEL revealed a significant warming range from 0.3 to 3.6 °C. The RegCM-SVN and ERA5 are almost similar in both simulations for T2m and SW at both scenarios, with strong correlation (> 0.90) over the entire oceanic area and over 0.85 (0.80) at the land area (southern part of the Gulfs of Aqaba and Suez) for both scenarios (RCP2.6 and RCP8.5). The validation processes indicated that RegCM-SVN successfully simulated the surface air temperature and wind regime over the study area. The simulated SW and T2m that are expected to have many socioeconomic negative impacts especially in tourism, agriculture, water demand, and health. Coastal processes including the current system, and marine biodiversity are also likely to be negatively affected by climate changes.

INTRODUCTION

The Mediterranean basin lies between 30° to 49° N and longitude boundaries between 10° W to 45° E as shown in Figure (1). This basin is surrounded by three continents: Africa, Asia, and Europe. The climate in this area is quite changeable between dry summers (warm to hot), and wet winters (mild to cool) **(Caloiero *et al*., 2018).**

The Mediterranean Sea is a semi-enclosed maritime environment that encompasses roughly 2.6 million km^2 and has a volume of 3.7 million km^3. It has an average depth of 1.46 kilometers. The Mediterranean Sea is divided to main basin Western and Eastern which separated by a strait of Sicily. These two basins are further divided into a series of linked portions and seas. The western basin is about 0.85 million km^2, whereas the eastern basin is about 1.65 million km^2 **(UNEP, 1989).**

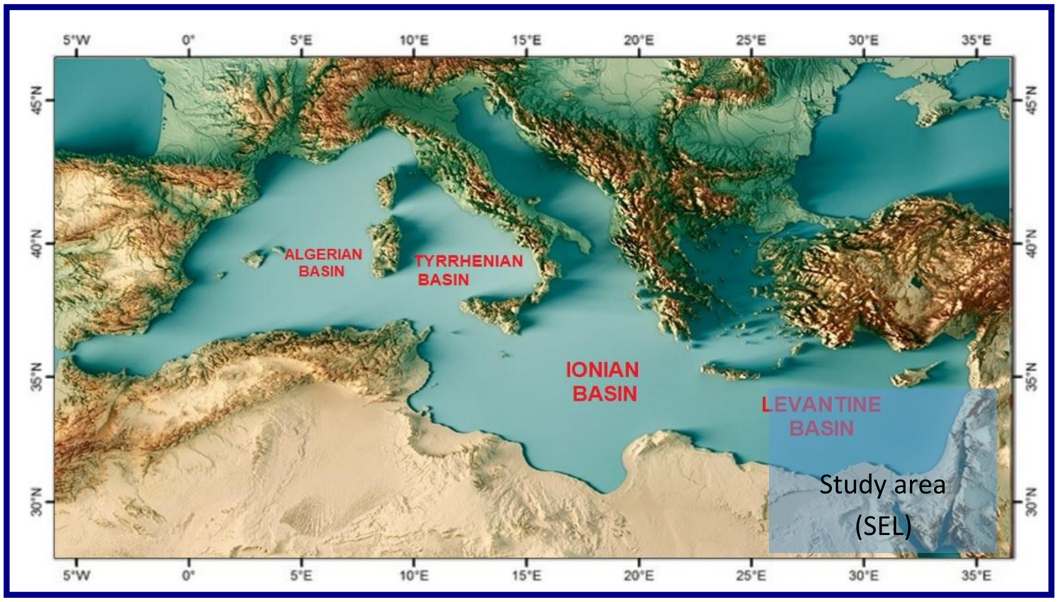

Figure 1. The Mediterranean Sea domain , main basins, and study area.

Moreover, the Mediterranean Sea is connected to the Atlantic Ocean via the Gibraltar Strait (14 km^2 wide), the Red Sea via the Suez Canal, and the Black Sea via the Marmara Sea. It has been occupied by human for millennia and subjected to multiple activities, reaching a critical level (a population of 150 million, plus 200 million tourists every year, pollution, overfishing, hazardous maritime traffic, exotic species, increasing coastal development), without considering the effects of climate and global changes **(IUCN, 2021).**

The Mediterranean region is affected by interactions between mid-latitude and tropical processes, as it is located in the transition zone between North Africa's arid climate and central Europe's temperate and rainy climate. Because of these features, even relatively minor modifications of the general circulation, e.g. shifts in the location of mid-latitude storm tracks or sub-tropical high-pressure cells, can lead to substantial changes in the Mediterranean climate. As a result, the Mediterranean is a potentially sensitive zone to climate changes caused, for example, by rising greenhouse gas concentrations **(Lionello *et al*., 2006** and **Ulbrich *et al*., 2006).**

There are two primary basins in the eastern Mediterranean. To the south of Italy, Albania, and Greece is the Ionian Basin, which comprises the Ionian Sea. The Ionian Basin is separated from the Levantine Basin to the south of Turkey (Anatolia) by a submarine ridge between the western end of Crete and Libya (Cyrenaica); and the

Levantine Basin is separated from the Aegean Sea by the island of Crete, which comprises that part of the Mediterranean Sea north of Crete and bounded on the west and north by the coasts of Greece and Turkey. The Greek archipelago's many islands are located in the Aegean Sea **(Boxer** and **Mostafa, 2021).**

As a result of the worldwide rise in GreenHouse Gas (GHG) concentrations, the Mediterranean area is one of the "Hot Spots" expected to suffer severe climatic changes in the twenty-first century **(Mariotti, 2011).** Furthermore, because of the possible risks and consequences on our environment in the near future, climate change has become a major focus of concern. Vulnerability evaluations in coastal regions are primarily concerned with Sea Levels Rising (SLR). Other non-climatic factors (such as socio-economic development) that can have a substantial impact on climate change are frequently overlooked, despite the fact that they are critical for climate and coastal management policy development **(Nicholls *et al*., 2008).**

The Egyptian Mediterranean coast is located between latitudes 30° to 33° North and longitudes 25° to 34.5° East, extending from Rafah in the east to El-Sallum in the west, with a total length of about 898.2 km^2. It has Five lakes: Idku, Burullus, Manzala,Maryut, and Bardaweal, as well as several important populated coastal cities along the coast and two promontories: Rosetta and Damietta **(Agrawla *et al*., 2004** and **El-Raey, 2010).**

Extreme weather and climate events can cause disasters when they interact with exposed and vulnerable human and environmental systems. The **IPCC (2012)** defined the Climatic Change as “change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or inland use”. Moreover, the Climate Extreme (extreme weather or climate event) is defined as″ the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. The both of extreme weather / climate events are referred to as a whole ‘climate extremes″. Furthermore, the impact is defined as ″the influence on natural and human systems of extreme weather and climate events and of climate change". The impacts in public refer to effects on livelihoods, lives, health, economies, ecosystems, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed system/society.

To address any adaptation to the climate changes or its mitigation, knowledge of detailed meteorological and oceanic information and their projection in the future must be well examined by employing advanced up-to-date approaches such as modeling. Understanding the long-term variabilities of surface air temperature and the wind is essential for the adaptation and mitigation plans over such hotspot marine areas. Recently released global atmospheric analyses represented a step-change tool for climate investigations; however, their resolution is still inadequate to describe regional/local climates and a downscaling procedure is needed to provide more reliable data and information to policy makers. So the understand the variabilities of T2m and wind speed (WS) in this region, is the main goal of this study for planning adaptation measures in different life sectors together with finding suitable regional climate policies to cope with climatic change issues in future.

2. Climatic Background

2.1 Surface air temperature (T2m) over SEL:

The T2m over SEL varies seasonally and spatially. In its coastal areas, the seasonal and diurnal variations of T2m are greater than the same over the open sea, in spite of sea breezes, which have an important moderating effect that prevents excessive afternoon temperatures in summer over coastal areas **(Egyptian Naval Forces, 1962).**

Hasanean and **Abdel Basset (2006)** used NCEP/NCAR data from 1960 to 2000 to confirm that T2m has monthly variation, where the minimum T2m occurs from December to February and the maximum T2m occurs from July to August over Egypt. Moreover, **Shaltout *et al*. (2013)** supported the previous finding by using the ERA-Interim dataset (1979–2010) along the Egyptian Mediterranean coast. More recently, **Tonbol *et al*. (2018)** used a series of observation data along the Egyptian Mediterranean coast for the period 2007-2018 and confirmed a similar monthly variation pattern in agreement with **Hasanean and Abdel Basset (2006) and Shaltout *et al*.(2013).**

Domroes and El-Tantawi (2005) stated a positive T2m trend along the Egyptian Mediterranean coast from 1971-2000 except Port Said. **Shaltout *et al*. (2013)** supported the findings of **Domroes** and **El-Tantawi (2005)** and stated that T2m over SEL had a linear trend ranged from 0.40 to 0.57°C/decade. Similarly, **Domroes** and **El-Tantawi (2005)** showed a general decrease in T2m along the Egyptian Mediterranean coast by using a long term observed data from 1941 to 2000. On the contrary, **Tonbol *et al*. (2018)** determined a general positive T2m trend along the Egyptian Mediterranean coast with an average rate of 0.56°C/decade.

2.2 Surface wind regime over SEL:

Using the satellite wind data (Quick Scatterometer, QuikSCAT) for the period of 2000–2004, **Zecchetto** and **De Biasio (2007)** confirmed that the dominating wind direction over SEL, in general, came from Northwest (NW). In addition, **Krichak *et al*. (2007)** used the RegCM3 regional climate model to downscale results of Atmosphere-Ocean Global Climate Model (AOGCM) simulations during 1961–1990 along the SEL of the Egyptian coast and stated that wind direction showed spatial variation, as the wind direction was NW mostly over the western part of SEL and turned to be WNW over the eastern part of SEL.

The wind direction over SEL showed seasonal variations, however, the prevailing annual wind direction blows from NW direction to N direction in front of Port Said and Alexandria **(Hamed, 1979;Hamed, 1983; Elsharkawy *et al*., 2016** and **Mahfouz *et al*., 2020). Hamed (1983) and Meligy (2000)** found that the prevailing winds over Alexandria during the winter season blow from NW, W, and SW, while the wind blow during the spring season from NW, N, and NE with some occasional blowing from S or SW. The prevailing winds during the summer season came mainly from the NW direction and frequently from W and N directions, while the prevailing winds during the autumn season were mainly between NW, N, and NE with some occasional blowing from SW and W directions.

The SEL wind regime in wintertime is characterized by frequent short periods of 2.4 days of severe weather (hereinafter called Nawat; >17 m/s that occurs between clear or sunny spell intervals. There are 21 identified Nawat intervals that frequently occur over the study area extending from 17 October to 3 April (EAMS, 2021). In general, all Nawat periods are associated with cold fronts with a sudden fluctuation of wind, usually to the N or NW. In summertime, SEL is characterized by hot dry weather. The Asian anticyclone in summer extends westwards to Europe and normally collapses with an Eastern extension of the Azores anticyclone and cyclone over Syria, erupting from N to NW airflow over the Eastern Mediterranean Region **(Egyptian Naval Forces, 1962).**

2.3 The future climatological projection simulation:

The global mean temperature for 2020 during period from January to October 2020 was 1.2 ± 0.1 °C above the pre-industrial levels (1850-1900). 2020 is second of the three warmest years (2016,2019 and 2020) on record globally. The evaluation is based on five global temperature datasets (The two reanalysis “ERA5 and JRA-55” are aligned with the in-site data sets (HadCRUT, NOAAGlobal Temp and GISTEMP). The five data sets currently placed 2020 as 2nd warmest for the year to date when compared to similar periods in the past (January to October). The spread of the five estimates for the January to October average is between 1.11 °C and 1.23°. In 2019, the greenhouse gas concentrations recorded new highs globally, with the averaged of carbon dioxide (CO_2), methane (CH4), and nitrous oxide (N_2O) set reached to 410.50.2 parts per million (ppm), 18772 parts per billion (ppb), and 332.00.1 ppb respectively compared to pre-industrial levels **(WMO, 2020).** While in 2020, a temporary reduction in emissions of CO2 concentration related to measurement taken in response to coronavirus diseases (COVID-19) showed a slight decrease in the annual growth rate of CO2 in the atmosphere **(WMO, 2020).**

Brown *et al*. (2008) demonstrated that statistical bias reductions are required for enhancing Regional Climate Model (RCM) performance. Furthermore, the RCM's improved simulations by relying on the data provided by GCMs. Moreover, because the RCM incorporates a large number of physical parameters and dynamical methods, it can produce radically diverse outputs even when pushed by the same GCM. The RCM's grid size resolution is more than 3 km, necessitating additional analysis to acquire station-scale information. Statistical methods can close the gap between 3 km resolution and station-scale data.

RCP2.6, RCP4.5, RCP6, and RCP8.5 are the IPCC's Representative Concentration Pathways (RCP) defined as greenhouse gas (emissions and concentration) path adopted by the IPCC. The pathways describe different futures climate status. The RCP2.6 represents a low greenhouse gas emission and high future mitigation, which, in Coupled Model Intercomparison Project Phase 5 (CMIP5) simulations, gives a two-in-three chance of limiting global warming to below 2 ˚C by 2100. By contrast, RCP8.5 describes a high greenhouse gas emissions scenario in the absence of policies to combat climate change. RCP`s scenarios are designed to describe different level of greenhouse emissions and subsequently the associated radiative forcing. RCP 2.6, 4.5, 6.0 and 8.5 w/m^2. The radiative forcing targets per m² were set at 2.6, 4.5, 6.0 and 8.5 W/m² century. RCP 8.5 is considered the worst pathway where high emissions are continued without effective mitigation at the end of this century. Combined with a population growth to around 13 billion later this century, high energy demand and slow technology development/uptake emissions continue to increase beyond 2100 as shown in Table (1) **(Moss *et al*., 2010** and **Van Vuuren *et al*., 2011;).**

Table 1. The RCPs scenarios (RCP 2.6 and RCP 8.5) and their representative concentration pathways **(Moss *et al*., 2010)**

RCPs	R. (Radiative forcing)	C. (Concentration)	P. (Pathway)
RCP2.6	Peak at ≃3 W/m^2 before 2100 and then declines	Peak at ≃490 CO_2-equiv. before 2100 and then declines	Peak and decline
RCP8.5	>8.5 W/ m^2 in 2100	>1,370 CO_2-equiv. in 2100	Rising

Hochman *et al.* (2017) used the Eight Model with data from National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR). Reanalysis was done for the available data on daily and 6 h timescales from 1948 to 2016 with a grid 2.5°× 2.5° spatial resolution, which participated in the fifth phase (CMIP5) for future periods simulation at mid-21st century (2046–2065) and end century (2081–2100) for RCP4.5 and RCP8.5 scenarios according to the recommendation of the Fifth Assessment Report (AR5) **(IPCC, 2013).**

The RCMs have more details for mountain ranges and coastal zones, as well as a description of smaller-scale atmospheric processes that lead to the production of mesoscale weather phenomena. The RCM characteristics are assumed to produce model output that is closer to certainty than the more coarsely resolved global model data, both for reanalysis for global scenario simulations **(Frauke *et al*., 2011).**

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Darmaraki *et al*. (2019) studied the future evolution (1976–2100) of Marine HeatWaves (MHWs) in the Mediterranean Sea, using the best dedicated multi-model ensemble available. According to the examination of six Regional Climate System Models from the Med-CORDEX (Mediterranean Coordinated Regional Climate Downscaling Experiment) initiative, driven by 4 CMIP5 GCMs under the RCP2.6, RCP4.5 and RCP8.5 scenarios, they found that the models well simulated marine heatwaves properties during historical period (1976-2005). Generally, MHWs become stronger in response to increasing GHG forcing and especially near the end of the century. RCP2.6, however, denoted a slight increase in MHW signatures with time but lower than RCP4.5 and RCP8.5.

The Med-CORDEX domain is considered as a hotspot area of climate change, especially vulnerable to warming trends coupled with drought trends **(Giorgi** and **Lionello, 2008; Ulbrich *et al.*, 2012).** The current warming trends over the Mediterranean region were approximately 1.5 times the global rate **(MedECC, 2020).** The network of Mediterranean Experts on Climate and Environmental Change MedECC (2020) showed that the Mediterranean basin air temperature is now 1.4°C higher than during 1880-1899. Moreover, **Giorgi** and **Lionello (2008)** concluded that the air temperature over the Mediterranean Sea will experience warming trends during the current century under A1B scenario of 2-3°C during cold seasons and of 3-4°C during hot seasons. In addition, **IPCC (2014)** showed that the air temperature over the Mediterranean region in the end of the current century will increase relative to 1986–2005 by 2 – 6°C under the four RCPs scenarios.

Giorgi *et al*. (2001) and **Jones *et al*. (2004)** declared that the using of regional climate model is considered as the best tools for dynamical downscaling from global climate models.

Data AND METHODS

3.Data Used:

3.1 Data Used to Force RegCM-SVN:

a. Data of air temperature, geopotential height, relative humidity, and zonal/meridional wind components were obtained from ERA5 hourly data on 38 different pressure levels from 1979 to 2018 with a grid spacing of 0.25° × 0.25°. ERA5 provides data on a denser spatial and temporal grid together with a significant improvement in core dynamics and model physics (Hersbach et al., 2020). ERA5 presents a long-term record of world climate and weather by assimilating observational data (from ground sensors and satellites) using the Integrated Forecasting System (IFS). It is an improvement over earlier re-analyses to be used for climate and meteorological scientific analyses (C3S, 2020).
b. ERA5 Sea Surface Temperature (SST) was also obtained using the ERA5 reanalysis database during the years of 1979–2018.
c. Static surface dataset is freely available via(http://climadods.ictp.it /Data/RegCM_Data/SURFACE/) and used to describe RegCM-SVN surface boundary conditions:

- GTOPO_DEM_30s, Digital Terrain Model Elevation with 30 arc seconds $\left(\frac{1^{\circ}}{120}\times\frac{1^{\circ}}{120}\right)$ spatial grid point.
- GLCC_BATS_30, Global Land Cover Characteristics with a spatial grid point of 30 arc seconds.
- GLZB_SOIL_30s, STATSGO/FAO soil texture with a spatial grid point of 30 arc seconds.
- ETOPO_BTM_30s, lake bathymetric datasets with a spatial grid point of 30 arc seconds.

3.2 ERA5 Hourly Reanalysis data:

a. Data of T2m and SW were obtained from ERA5 on an hourly basis with a spatial resolution of 0.25° × 0.25°. These data were used to validate the RegCM-SVN model results to gain confidence and give a full image of the variabilities of T2m and WS over the study area. This was done according to Copernicus Climate Change Service (C3S, 2020) and Hersbach *et al*. (2020); therefore, ERA5 can be used efficiently to describe the current dynamics of the atmospheric parameters.

b. Data of T2m and SW were obtained from ERA5 on an hourly basis with a spatial resolution of 0.25° × 0.25° for (2006-2020). These data were used to future projection simulation the RegCM-SVN model results to gain confidence and future projection simulation for two scenarios (RCP2.6 and RCP8.5).

3.3 RegCM-SVN model for the future projection simulation:

The future climate projection of the SEL was studied for the two adopted atmospheric parameters using regional climate model version 4 (RegCM-SVN) from 2005 up to 2100 of/with 25 km (0.22^{o}) grid resolution. The RegCM-SVN was driven with two CMIP5 scenarios (i.e. RCP2.6 and RCP8.5 from HADGEM global climate model). Moreover, the future climate change projections up to 2100 were identified over the territory of SEL for the surface Eastward Wind (U_{10}), Northward Wind (V_{10}) components and the Surface Air Temperature (T2m).

The RCP 2.6 is a " more friendly" pathway. RCP8.5 is generally taken as the basis for worst-case climate change scenarios (Wayne, 2013). Quantified measures of uncertainty in a finding expressed probabilistically was based on statistical analysis of model results based on RCP2.6 and RCP8.5 **(IPCC,2010)**.

RESULTS

4. RegCM-SVN Model for the Future Projection Simulation

4.1 RegCM-SVN Model for Recent Simulation (2006-2020):

a) The daily bias for simulation over SEL (2006-2020).

The daily bias of T2m between RegCM-SVN and ERA5 at the current simulation scenarios RCP2.6 and RCP8.5 (from 2006 to 2020) ranged from 0 °C to -1 °C especially over the oceanic area with homogeneity at both scenarios, while values are wide range varied over land area between -2 °C to +1 °C as shown in Figure (2). On the other hand, the daily bias of U_{10} and V_{10} ranged from 0 m/s to -1 m/s over oceanic area. Conversely, the southern part of the Gulfs of Aqaba and Suez showed obviously contrast up to -4 m/s (Figure 3 and Figure 4). The RegCM-SVN and ERA5 are almost similar in both simulations for T2m and SW at both scenarios.

b) The daily correlation for simulation over SEL:

The spatial correlation of T2m at the current simulation between RegCM-SVN and ERA5 showed a strong correlation (> 0.90) over the entire oceanic area and over 0.85 (0.80) at the land area (southern part of the Gulfs of Aqaba and Suez) for both scenarios (RCP2.6 and RCP8.5) as shown in Figure (5).

Over 40% of the study area, especially over the SEL basin, Nile Delta, and along the River Nile, the simulated U_{10} by RegCM-SVN and ERA5 showed a non-significant correlation with the U_{10} at both scenarios (Figure 6). Conversely, the simulated V_{10} showed a non-significant correlation over the entire oceanic area (from 0 to 0.15), while on the land area the correlation was over 0.20 as shown in Figure (7).

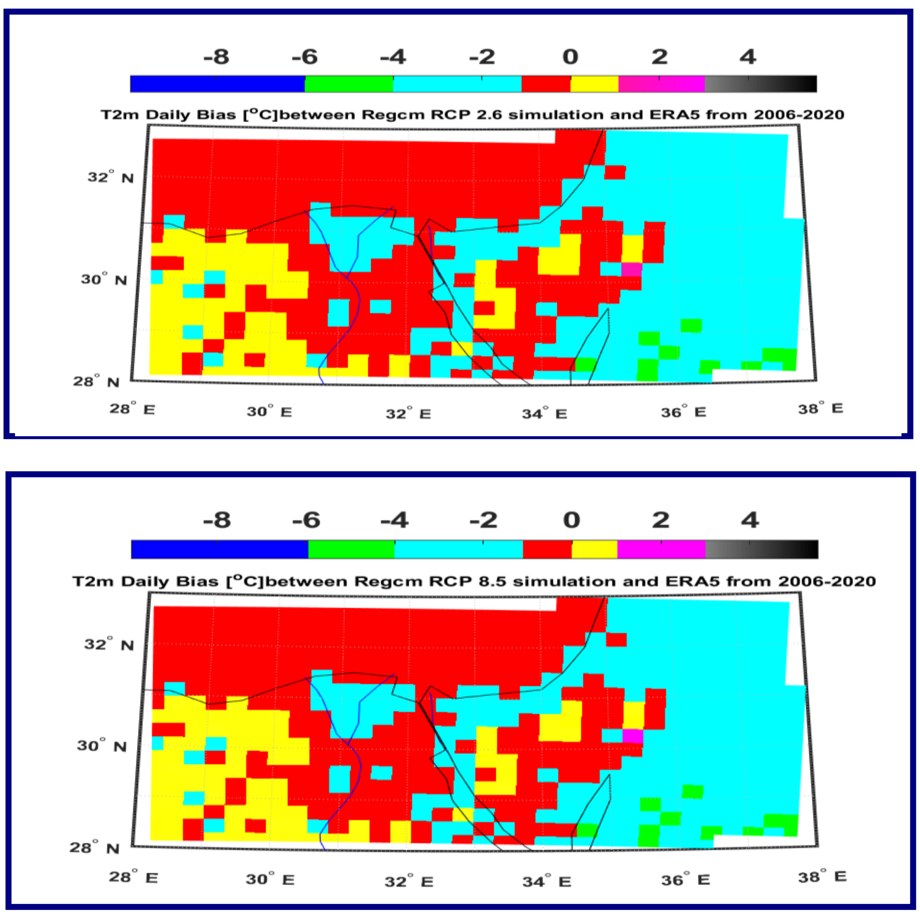


Figure 2. The daily bias Simulation of T2m between RegCM-SVN and ERA5 driven by using two CMIP5 scenarios RCP2.6 and RCP8.5 from HADGEM over the SEL from 2006 to 2020.

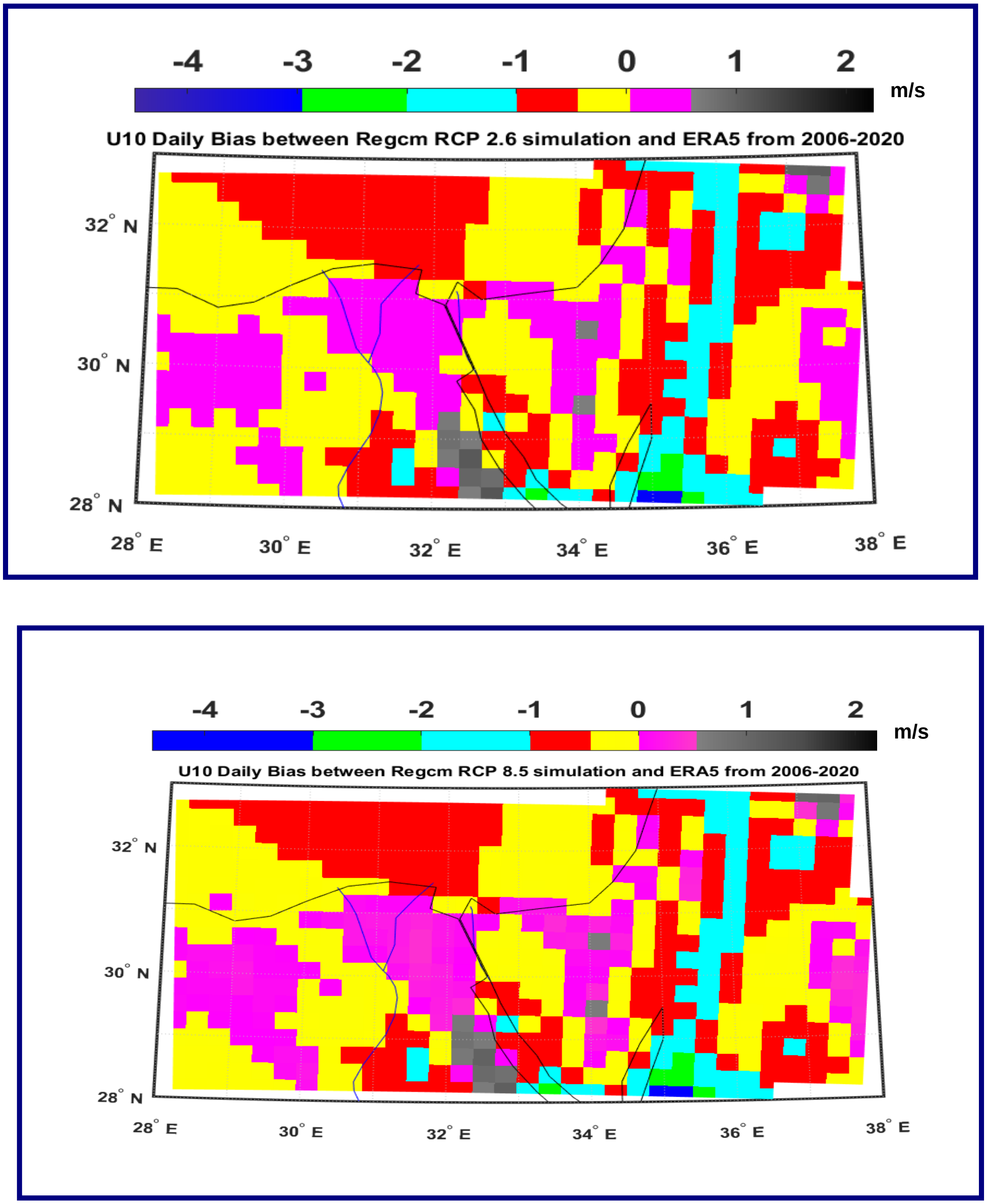


Figure 3. The daily bias Simulation of U_{10} between RegCM-SVN and ERA5 driven by using two CMIP5 scenarios RCP2.6 and RCP8.5 from HADGEM over the SEL from 2006 to 2020.

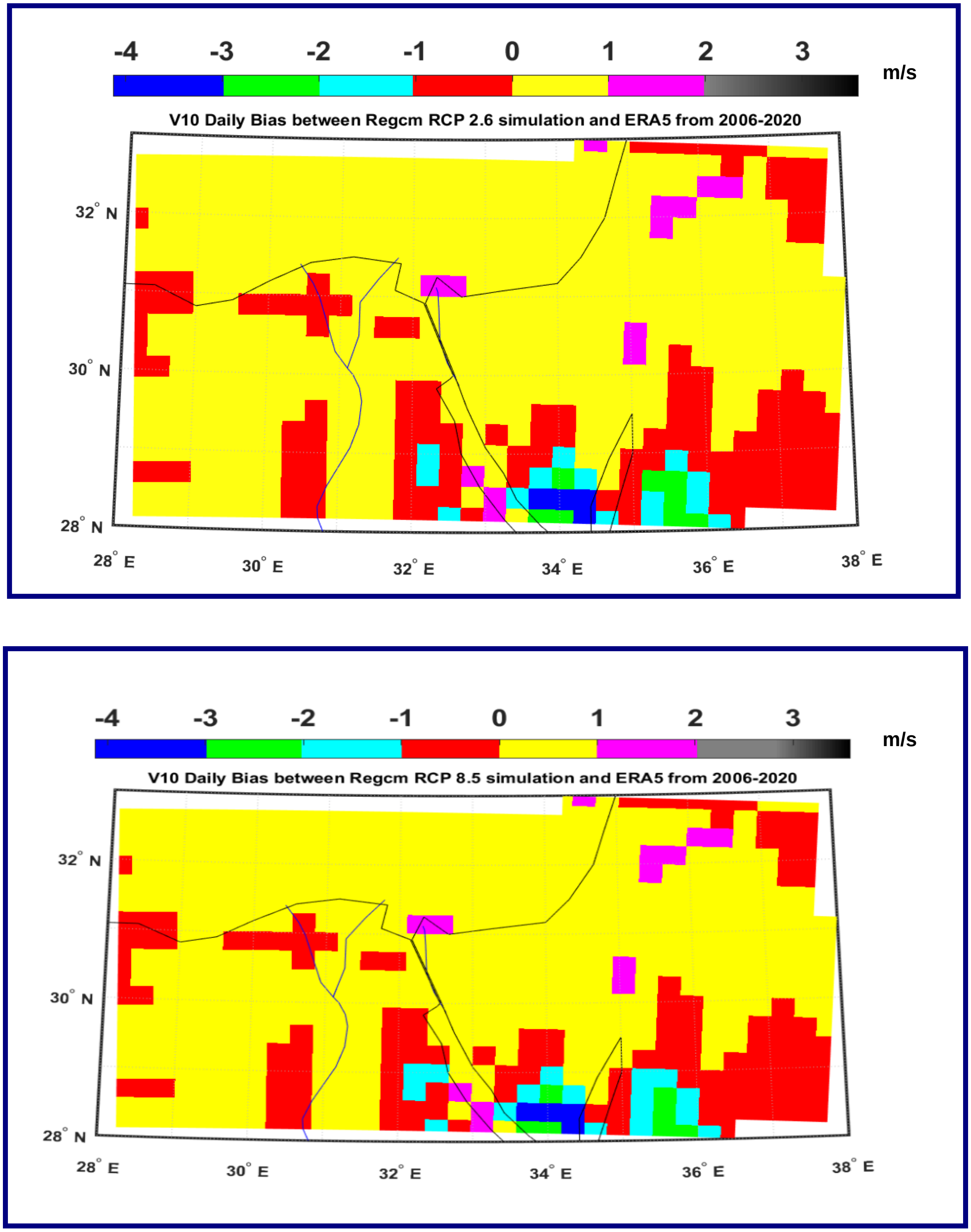


Figure 4. The daily bias Simulation of V_{10} between RegCM-SVN and ERA5 driven by using two CMIP5 scenarios RCP2.6 and RCP8.5 from HADGEM over the SEL from 2006 to 2020.

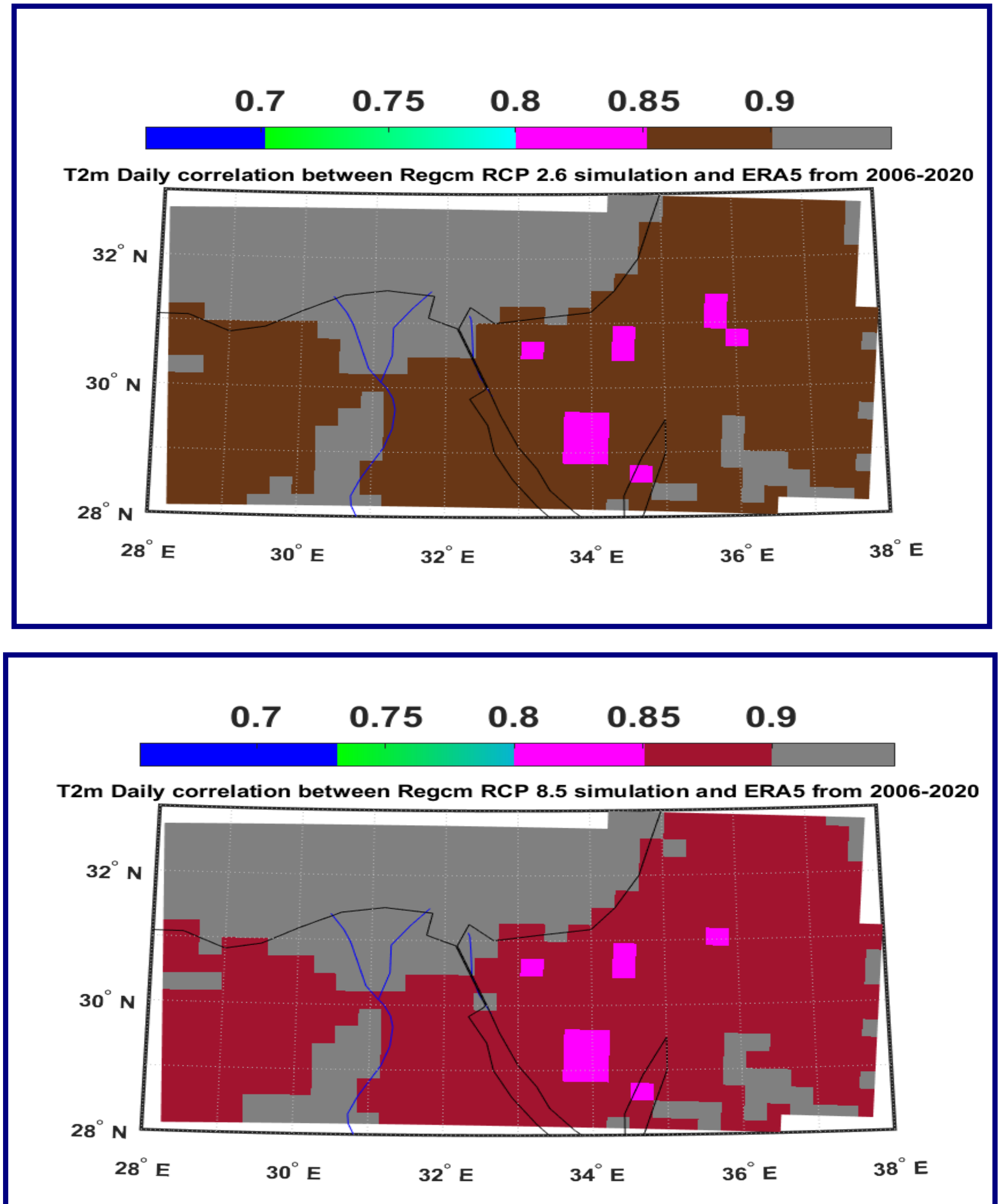
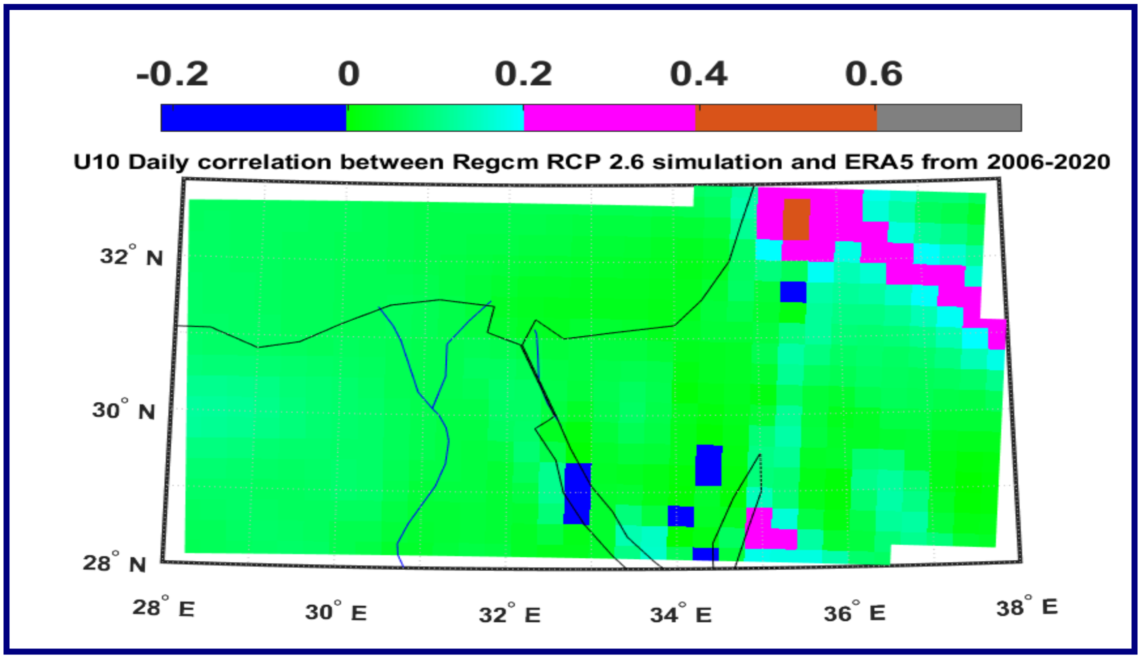


Figure 5. The daily correlation of T2m Simulation between RegCM-SVN and ERA5 over the SEL from 2006 to 2020.



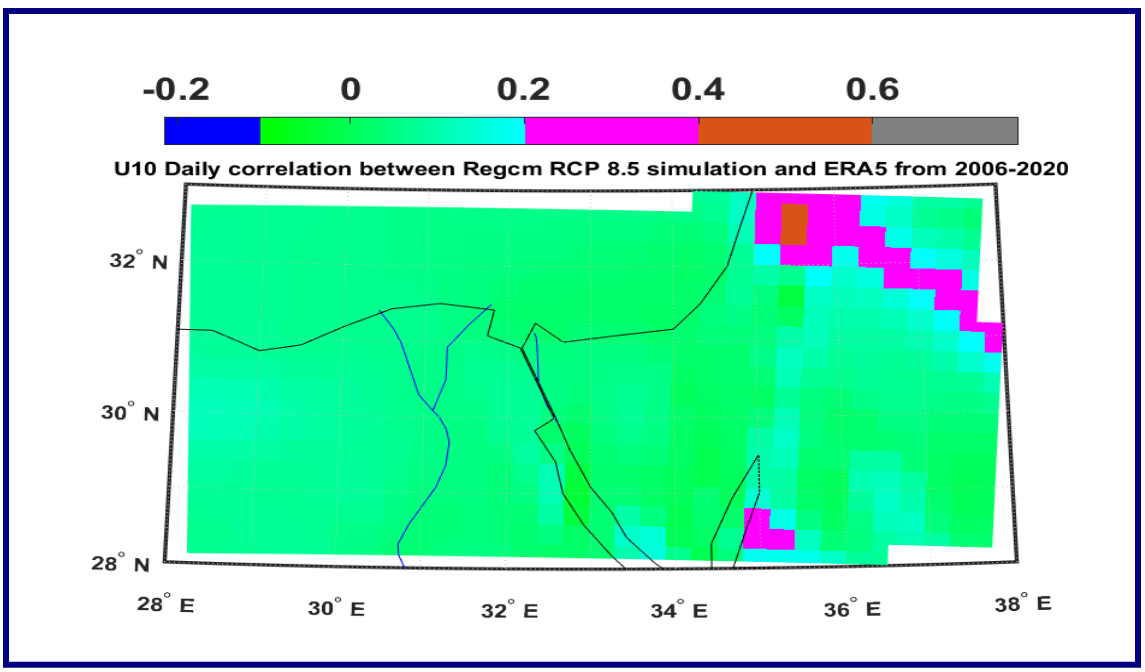


Figure 6. The daily correlation of U_{10} Simulation between RegCM-SVN and ERA5 over the SEL from 2006 to 2020.

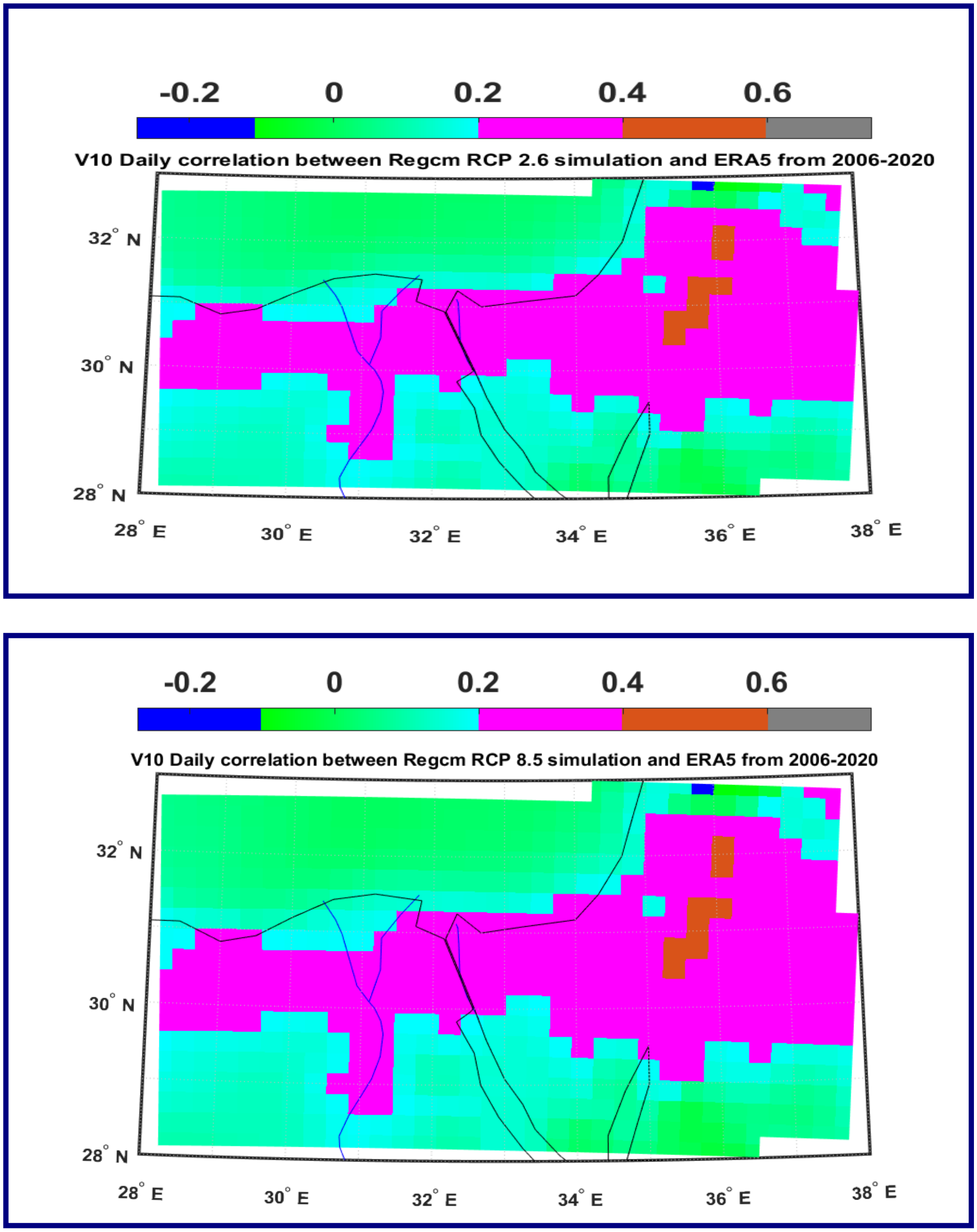


Figure 7. The daily correlation of V_{10} Simulation between RegCM-SVN and ERA5 over the SEL from 2006 to 2020.

4.2 The RegCM-SVN model for Future Projection Simulation (2020-2100):

The future projection simulation results of RegCM-SVN of T2m and surface wind field for the study area were examined to evaluate the accuracy of RegCM-SVN with thirty–year running annual mean (30-year averaging periods represented the many climatic parameters, WMO, 2007) for T2m to the end of the current century with reference to simulation (2005–2020) average for RegCM-SVN scenarios (RCP2.6 and RCP8.5) over the SEL.

The RegCM-SVN future projection simulation scenarios RCP2.6 for T2m showed the entire oceanic area ranging from 0 to +1°C, while land area and the Gulfs of Aqaba and Suez are underestimates from 0 to -2 °C (Figure 8 a). On the other hand, the future simulation scenarios RCP8.5 showed overestimates (> +2°C) over SEL except North gulf Suez was less than +2°C (Figure 8b).

The RegCM-SVN future projection simulation scenarios (RCP2.6 and RCP8.5) for U10 showed homogeneity over SEL with underestimates (from 0 to -0.5 m/s), with at the interaction oceanic area and land which decreased in scenario RCP8.5 (Figure 9). There is a difference in the future simulation for V10 between scenarios RCP2.6 and (RCP8.5) which ranged from 0.25 to -0.25 m/s (underestimates from 0 to -0.25m/s) with differentiation at the western land area and Gulfs of Aqaba and Suez with underestimates from -0.25 to -0.75 m/s (Figure 10).

For the period 2020–2100, the projected T2m showed increased anomaly uncertainty according to the used scenarios ranged from 0.3°C (RCP2.6) to 3.6°C for scenario (RCP8.5) compared with 2020. The U10 showed a decreasing uncertainty according to the used scenarios ranged from -0.02m/s (RCP2.6) to -0.11m/s for scenario (RCP8.5). While the V10 showed increasing uncertainty according to the used scenarios ranged from -0.01m/s (RCP2.6) to -0.10m/s for scenario (RCP8.5) as shown at Figure (11).

The results of future simulation for T2m, U10 and V10 (2020-2100) by using RegCM-SVN scenarios (RCP2.6 and RCP8.5) over the SEL generally showed an oscillizating increase of scenario RCP8.5 (up /down) than scenario RCP2.6 at both parameters (T2m and surface wind regime). The temperature will increase continuously in the future, and the temperature increase under RCP8.5 scenario would be significantly larger than under RCP2.6 scenario.

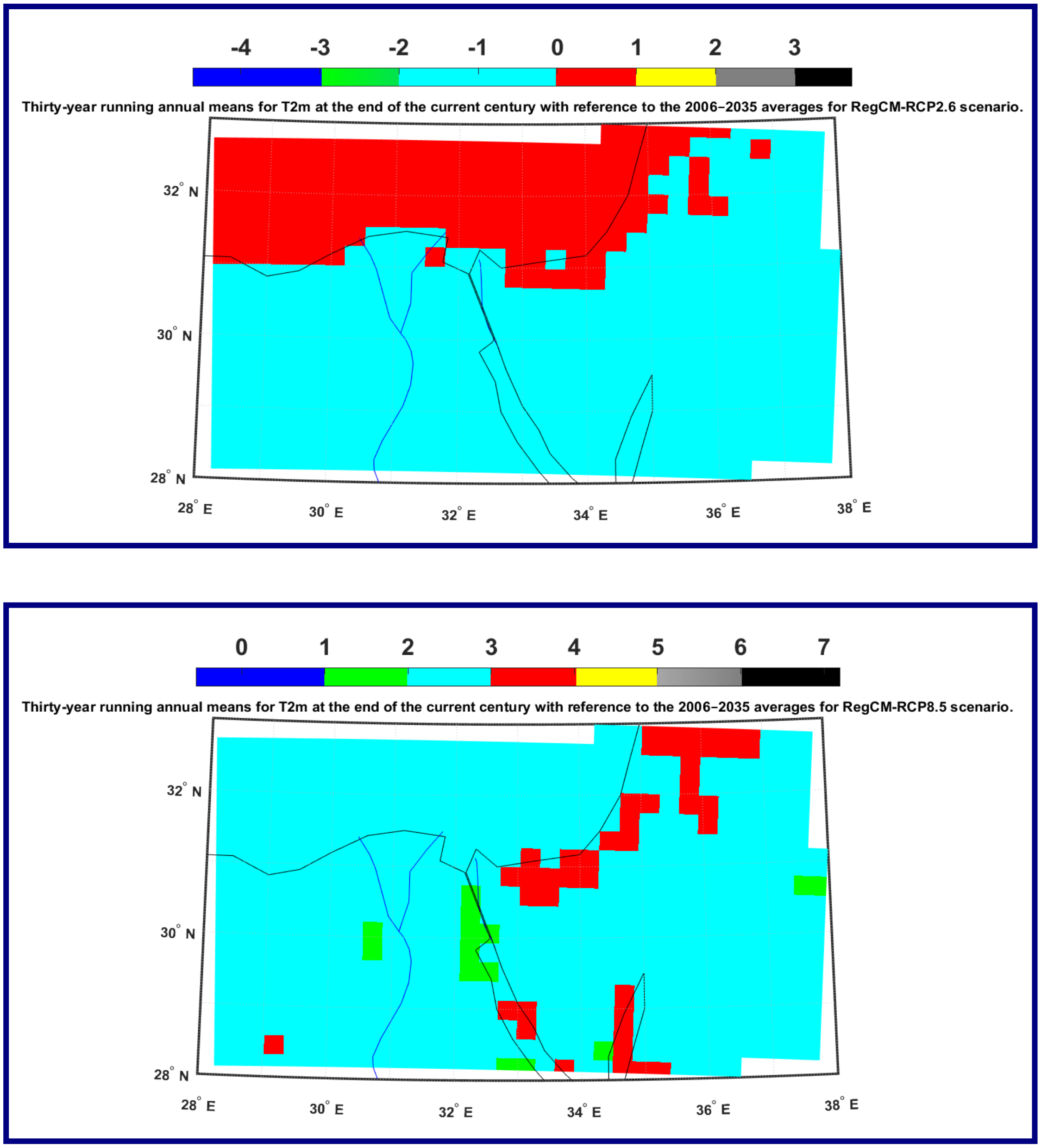
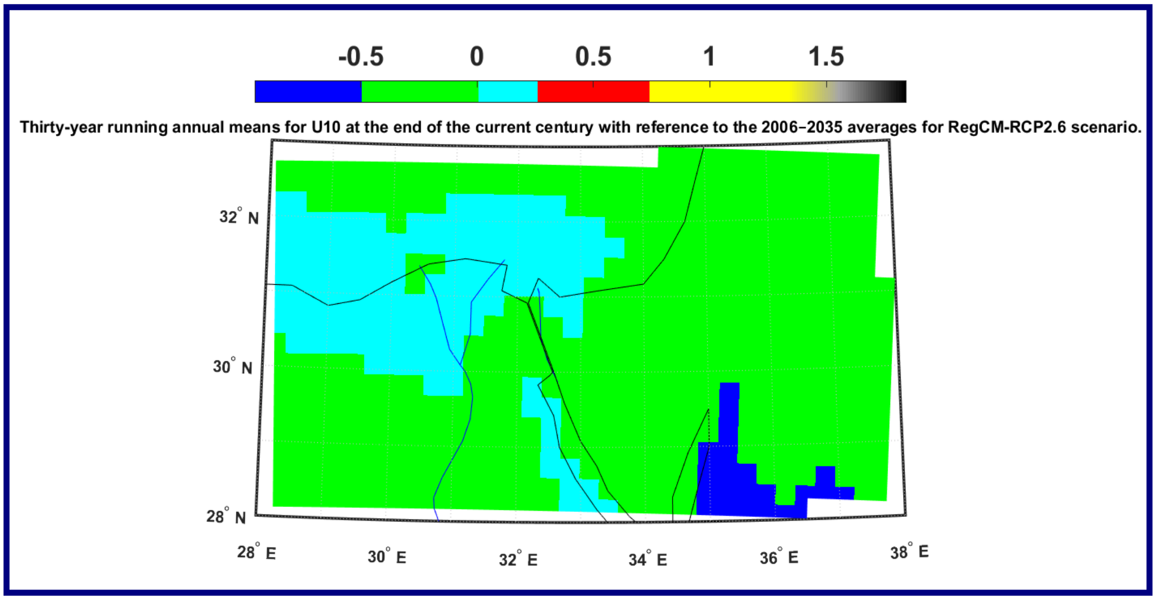


Figure 8. The thirty–year running annual mean for T2m to the end of the current century with reference to simulation (2006-2020) average for RegCM-SVN scenarios (RCP2.6 and RCP8.5) over the SEL.



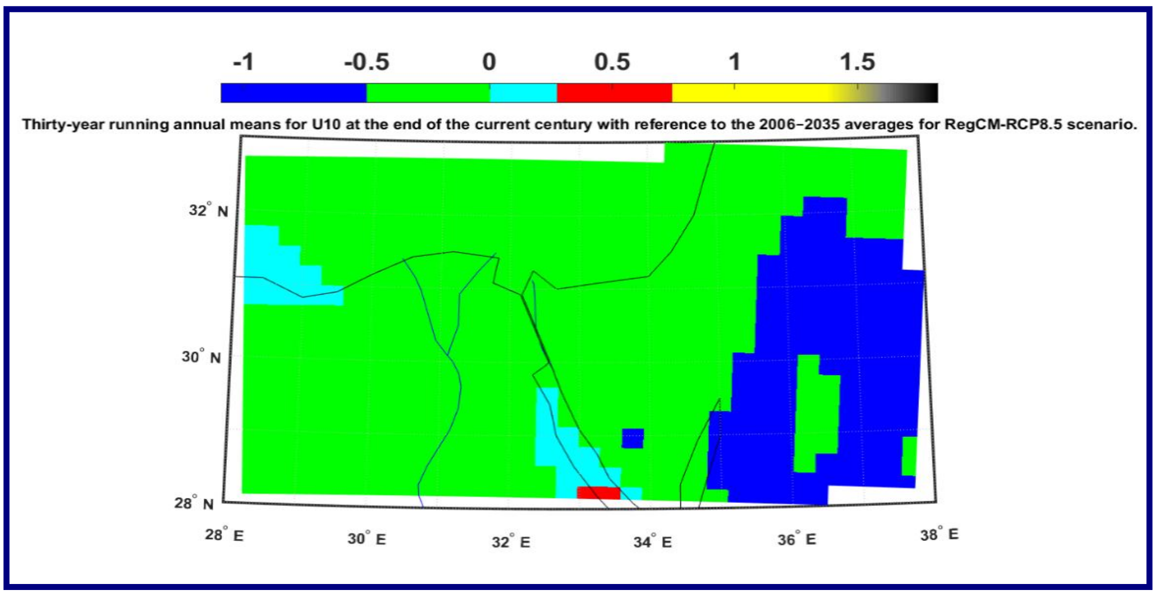


Figure 9. The thirty–year running annual mean for U_{10} to the end of the current century with reference to simulation (2005-2020) average for RegCM-SVN scenarios (RCP2.6 and RCP8.5) over the SEL.

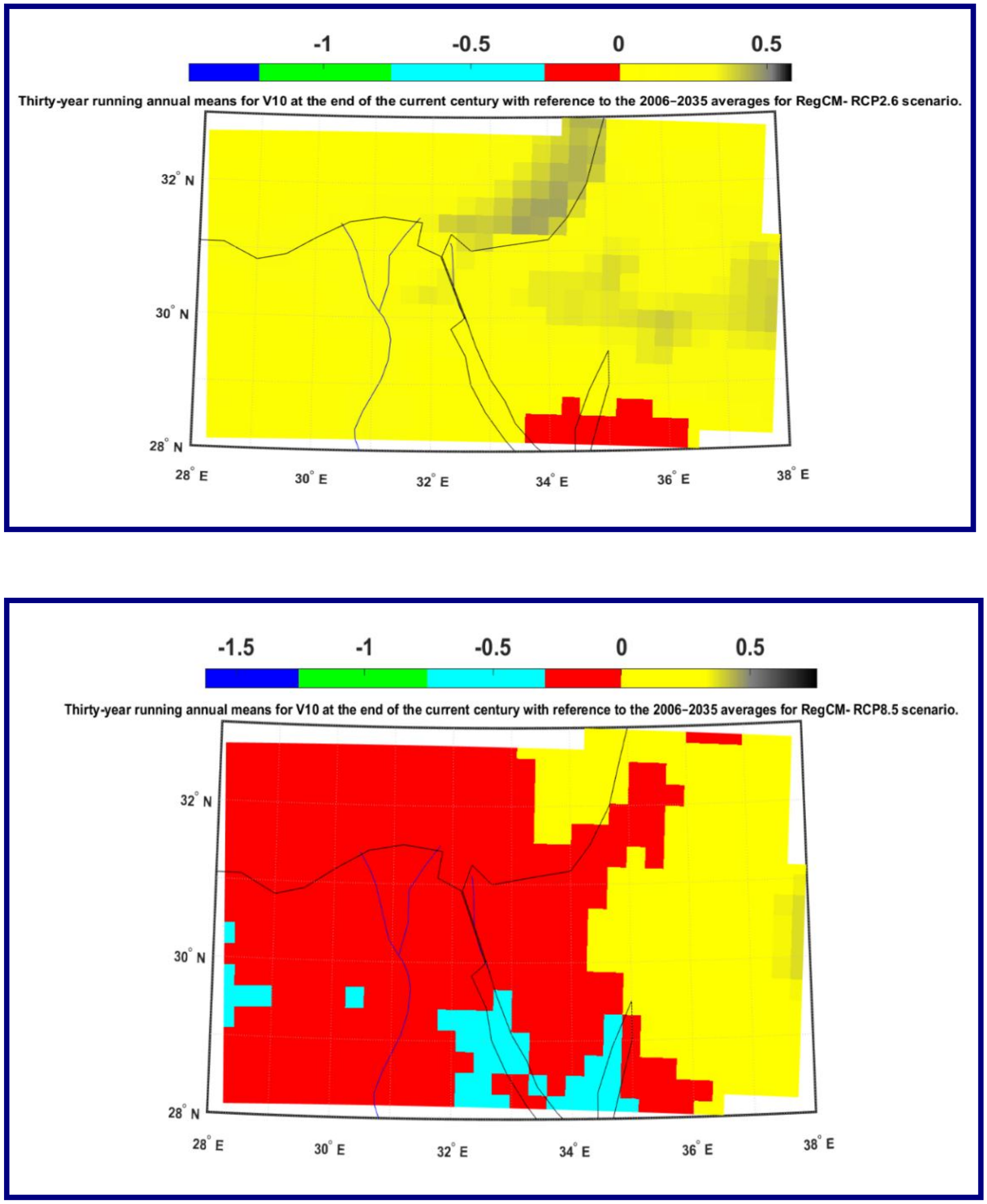


Figure 10. The thirty–year running annual mean for V_{10} to the end of the current century with reference to simulation (2005-2020) average for RegCM-SVN scenarios (RCP2.6 and RCP8.5) over the SEL.

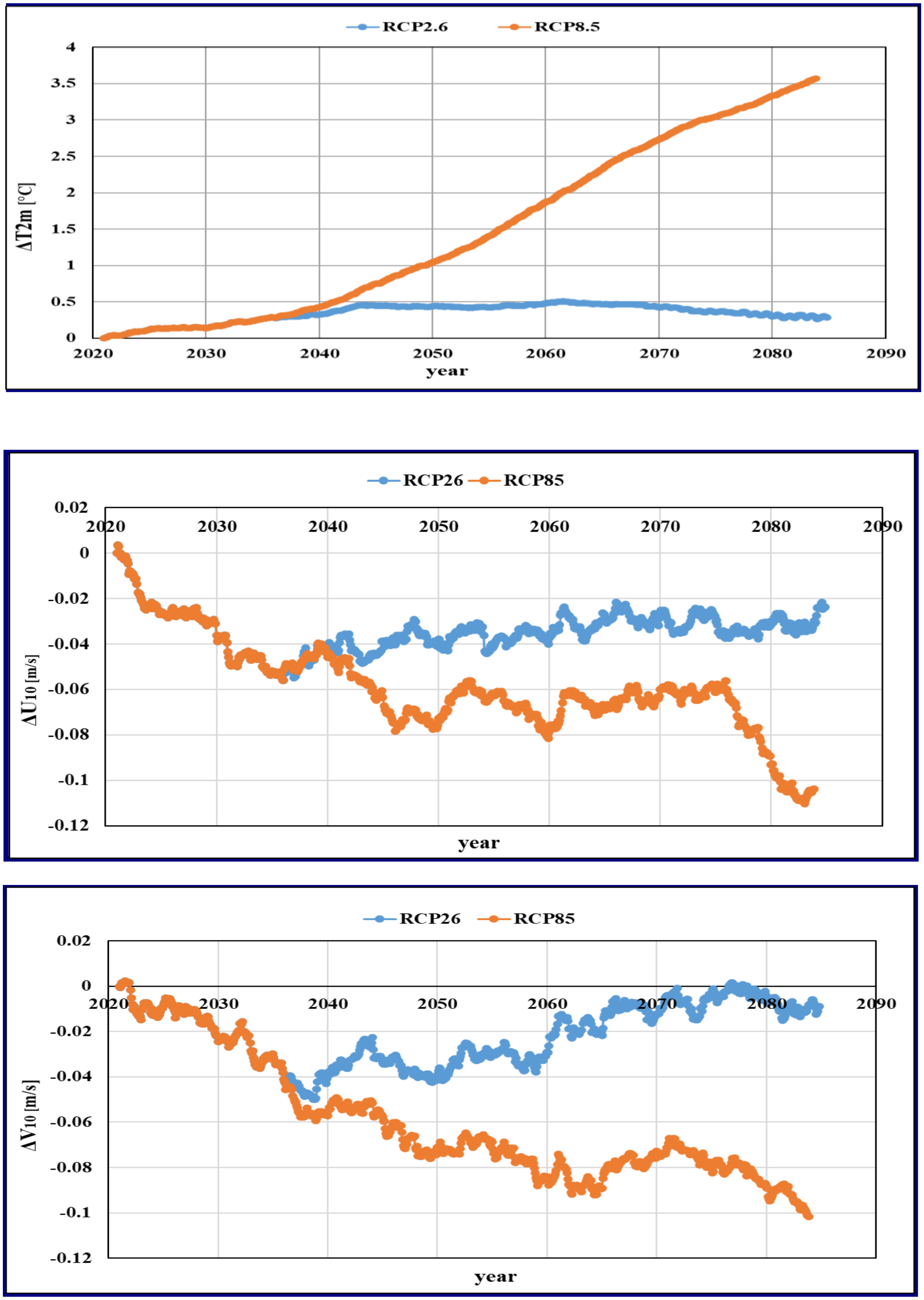


Figure 11. The future projection simulation for T2m, U_{10} and V_{10} (2020-2100) for RegCM-SVN scenarios (RCP2.6 and RCP8.5) over the SEL. Δ: changes based on 2020 data.

DISCUSSION

The present work sheds light on the current and future simulation scenarios RCP2.6 and RCP8.5 (from 2006 up to 2100) for surface air temperature and wind regime over the southeastern Levantine Basin and its surrounding areas. As far as we know, the current study is considered the first try to project the atmospheric parameters over Egypt using fine scale of 30km. In the previous work, the study area is a part of the study domain. Thus, the T2m and SW over the study region were effectively simulated by the RegCM-SVN, which exhibited similar accuracy to the ERA5 in characterizing the surface SW and T2m over the study area. In details, the daily bias of T2m between RegCM-SVN and ERA5 at the current simulation scenarios RCP2.6 and RCP8.5 (from 2006 to 2020) ranged from 0 °C to -1 °C especially over the oceanic area with homogeneity at both scenarios, while values are wide range varied over land area between -2 °C to +1 °C. Moreover, the daily bias of U_{10} and V_{10} ranged from 0 m/s to -1 m/s over oceanic area. Conversely, the southern part of the Gulfs of Aqaba and Suez showed obviously contrast up to -4 m/s. The RegCM-SVN and ERA5 are almost similar in both simulations for T2m and SW at both scenarios.

Generally, the RegCM-SVN and ERA5 showed strong correlation (> 0.90) over the entire oceanic area and over 0.85 (0.80) at the land area (southern part of the Gulfs of Aqaba and Suez) for both scenarios (RCP2.6 and RCP8.5).

The RegCM-SVN future projection simulation scenarios RCP2.6 for T2m showed the entire oceanic area ranging from 0 to +1°C, while land area and the Gulfs of Aqaba and Suez are differed. On the other hand, the future simulation scenarios RCP8.5 showed overestimates (> +2°C) over SEL except North gulf Suez was less than +2°C. Moreover, the future simulation scenarios (RCP2.6 and RCP8.5) for U_{10} showed homogeneity over SEL, with at the interaction oceanic area and land which decreased in scenario RCP8.5. There is a difference in the future simulation for V_{10} between scenarios RCP2.6 and (RCP8.5) with differentiation at the western land area and Gulfs of Aqaba and Suez.

The RegCM-SVN future projection simulation scenarios the period from 2020 up to 2100, the T2m showed increased anomaly according to the used scenarios ranged from 0.3°C (RCP2.6) to 3.6°C for scenario (RCP8.5), and this results agreement with WMO (2020) for global warming. On the other hand, the U10 showed a decreasing uncertainty according to the used scenarios RCP2.6 and RCP8.5). While the V10 showed increasing ranged from -0.01m/s (RCP2.6) to -0.10m/s for scenario (RCP8.5).

Finally, the results of future simulation for T2m, U10 and V10 (2020-2100) by using RegCM-SVN scenarios (RCP2.6 and RCP8.5) over the SEL showed an oscillizating increase of scenario RCP8.5 (up /down) This is due to the precautionary measures that may be taken to limit climate change in the future, according to the scenario than scenario RCP2.6 at both parameters (T2m and surface wind regime). The temperature will increase continuously in the future, and the temperature increase under RCP8.5 scenario would be significantly larger than under RCP2.6 scenario

The difference in results of SEL related to the diversity in the nature of the study area from the oceanic ,Nile Delta to the desert region, as well as mountain series, which impacts any climatic model, which must be taken into consideration for future work to improve the model's accuracy.

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