© 2018 IJSRSET | Volume 4 | Issue 1 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology

Monitoring the Changes of Temperature Indices Under Climate Change Conditions

Khalil A.A.
Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Egypt

ABSTRACT

Weather and climate temperature extreme events may have major impacts on society, economy, ecosystems, and on human health; they drive natural and human systems much more than the average climate. The aim of this study is to monitor and analyze the changes of temperature indices based on future climate data in Egypt. The monitoring has been done based on assessing the changes of four temperature indices (Maximum maximum temperature (TXx), Minimum minimum temperature (TNn), Frost days(FD) and summer days(SU)) according to future climate data. The climate change data has obtained from downscaling global climate model ECHAM6 of scenario RCP 4.5 by a horizontal resolution 50 km during the period from 2010 up to 2090, and the results indicated that the highest TXx observed during the period 2080-2089 while lowest TNn observed during the period 2010-2019 in the most of Egypt governorates. Also, it has been observed that the maximum number of frost days was observed in 2010 decade while the maximum number of summer days in winter season was observed in 2080 decade at most of Egypt governorates.
Keywords: Maximum and Minimum Temperatures, Temperature Indices and Climate Change.

I. INTRODUCTION

Extreme weather events can have severe impacts on human health, built infrastructure, the natural environment, the transport sector and the economy at large. Extreme events in recent years have drawn increased attention to the science seeking to understand their causes (Kerr 2013). The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (Stocker *et al.* 2014) concluded that strong evidence exists for increases in some extremes worldwide since 1950, especially more frequent hot days and heavy precipitation events (Stephanie C., *et al.* 2014). It is, therefore, necessary to develop and apply seasonal forecast, climate prediction and climate projection modelling tools and capacities in all countries to enable scientists to provide the information needed to inform policy-making and decision-making on climate change adaptation and measures to enhance resilience across the all countries special in the Arab region (United Nations report, 2015). The annual, seasonal and monthly mean values of temperature, precipitation, and other common variables provide essential and indispensable information regarding the climate and how it may change; they are typically not directly link to climate impacts. During the last few years, the need for information more directly linked to impacts has resulted in a wide range of climate indices. Climate indices have developed to a simplified way communicate more complex climate change impact relations. Most studies of climate extremes are limited to the last ~ 50 years or less, simply because longer-term daily datasets have not commonly digitized. Furthermore, where long-term data are available, uncertainties about their homogeneity limit their use in studies of extremes (Paula J., *et al.* 2014). However, the global study by Alexander et al. (2006) showed an asymmetric temperature shift associated with greater warming in minimum temperatures than maximum temperatures and precipitation changes toward wetter conditions. There have also been increases in the growing season length, an increase in the number of frost-free days, and a decrease in the number of cold nights globally. The agriculture sector is highly sensitive to climate variability and weather extremes. Extreme weather events are increasingly threatening the farmers and agricultural production, it causing serious losses and damages increasingly gradually in Egypt (Khalil and Hassanein, 2016). Extreme weather events that occur in every agricultural region of the world, cause severe crop and livestock damage. Extreme weather events can affect the crops both via negative impacts on plant physiological processes and direct physical damage, as well as by affecting the timing and conditions of field operations. For instance, above-threshold temperatures and precipitation lows, leading to heat and drought stress, can negatively affect crop photosynthesis and transpiration (Porter and Semenov 2005), as well as increased pest and disease incidence; and extreme temperature events may also hinder fruit setting and development, critically lowering yield potential (Tubiello et al. 2007). The objective of this study is to monitoring and evaluates the changes of temperature indices under future climate in Egypt.

II. METHODS AND MATERIAL

A. Study areas

The study areas were conducted on the 16 governorates distributed on different climatic regions in Egypt (Lower, Central and Upper Egypt) according to the table 1.

Table 1: Coordinates of the studied locations.

No.	Location	Latitude [°N]	Longitude [°E]	No.	Location	Latitude [°N]	Longitude [°E]
1	Alexandria	31.20	29.95	9	Giza	30.05	31.22
2	Beheira	31.03	30.46	10	Beni Suef	29.07	31.07
3	Kafr el-Sheikh	31.12	30.95	11	Faiyum	29.30	30.85
4	Ismailia	30.60	32.28	12	Minya	27.74	30.83
5	Sharqia	30.58	31.50	13	Asyut	27.20	31.17
6	Gharbia	30.82	31.93	14	Sohag	26.60	31.78
7	Dakahlia	31.20	31.40	15	Qena	26.18	32.73
8	Monufia	30.60	31.02	16	Aswan	23.97	32.78

B. Future climate data

The future climate data has obtained from the downscaling process on global climate model (ECHAM6) of scenario Representative Concentration Pathways RCP 4.5 by a horizontal resolution 50 km using regional climate model (RegCM 4). The temperatures data have exported and analyzed from 2010 up to 2090 for the determined governorates to monitoring the changes of temperature indices based on future data.

C. Temperature Indices

Evaluating the changes in temperature indices in future years will be done based on studying four extreme indices (Maximum maximum temperature (TXx), Minimum minimum temperature (TNn), Frost and summer days (FD&SU)) as shown in table (2). These indices have been recommended by the groups such as the World Meteorological Organization (WMO), CCl/CLIVAR/JCOMM Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDI), the European Climate Assessment (ECA), and the Asia-Pacific Network (APN) (Alexandera, and Tebaldi, 2012) have aimed to provide a framework for defining and analyzing these indices, so that the results from different countries could be combined seamlessly (Peterson and Manton, 2008). The studied time series from 2010-2090 were assessed every ten years.

Table 2: Determined extreme temperature indices

Index	Indicator Name	Indicator Definitions	Units
	A. Intensity		
Tnn	Min Tmin	*Monthly minimum value of daily min temperature*	*°C*
Txx	Max Tmax	*Monthly maximum value of daily max temperature*	*°C*
	B. Frequency		
SU	Summer days	*Annual number of days when Tmax >25 °C*	*days*
FD5	Frost days	*Annual count when daily minimum <5 °C*	*days*

III. RESULTS AND DISCUSSION

The results of temperature indices were calculated for the governorates which mentioned in table 1 for the years from 2010 up to 2090 and then studying the extremes in every 10 years for the winter (DJF), Spring (MAM), Summer (JJA), and Autumn (SON) seasons.

The results have been classified according to the geographical locations,

A. Lower Egypt Governorates

TXx and TNn in Lower Egypt governorates **(**Alexandria, Beheira, Kafr el-Sheikh, Ismailia, Sharqia, Gharbia, Dakahlia, and Monufia) are shown in tables (3, and 4) which indicated that the highest TXx values in the winter season(DJF) observed during the period 2080 – 2089 at all Lower Egypt governorates except at Dakahlia where its highest TXx observed during the period 2030-2039. The same observation was found in the spring season (MAM) but the exception in this season observed in Alexandria and Dakahlia where their highest TXx occurred during the periods 2070-2079, and 2010-2019 respectively.

In the summer season (JJA), the highest TXx was observed during the period 2060-2089 where it was during 2060-2069 at Beheira, during the period 2070-2079 at Alexandria, Kafr El-sheikh, Sharqia, and Monufia, and during the period 2080-2089 at Ismailia, Gharbia, and Dakahlia.

In autumn season (SON) the highest TXx was found during the period from 2080 - 2089 in all lower Egypt governorates except at Beheira and Dakahlia where their highest TXx recorded during the period 2070 - 2079.

From table (4) which shows the values of TNn in the mentioned periods, we can observe that the Lowest TNn at Lower Egypt governorates were found during period 2010-2019 in the winter season except at Ismailia and Gharbia where its lowest TNn observed during the period 2030-2039 and during 2060-2069 respectively.

In the spring season, the lowest TNn observed during the period 2010-2019 at Sharqia, Dakahlia, and Monufia, during the period 2020-2029 at Beheira, Kafr El-sheikh, and Ismailia, during 2050-2059 at Alexandria, and during 2060-2069 at Gharbia, while in summer season the lowest TNn observed in all periods except 2070-2089.

In the autumn season, the lowest TNn observed during the period 2010-2019, except at Ismailia where its lowest TNn observed during the period 2070-2079.

Number of frost days were collected during each 10 years for the days that their daily minimum temperature was lower than 5 °C.

Figure (1) shows the number of frost days for studied Lower Egypt governorates, and it's observe that, the 2010 decade has the highest number of the frost days for all governorate except at Gharbia where the 2060 decade has higher record by 3 days, while the decade of 2070 has the lowest record of frost days at all governorates except at Dakahlia and Monufia, it was lower by 3 days in 2080 decade.

Number of summer days were collected during the study period every 10 years in their winter months (DJF) for the days that their daily maximum temperature was greater than 25 °C. Figure (2) shows the Number of summer days for studied Lower Egypt governorates, and it's observed that 2080 decade has the highest summer days at all lower Egypt governorates while the lowest record was in 2010 and 2020 decades with a very close records except at Gharbia where its lowest record observed during 2060 decade.

Table 3: Seasonal Maximum Maximum temperature for Lower Egypt governorates

Winter								
	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089
Alexandria	28.3	26.9	34.4	29.7	31.5	32.4	34.4	37.2
Beheira	28.5	28.6	34.0	29.4	32.0	32.8	34.0	36.9
Kafr El-sheikh	29.0	27.3	33.6	29.4	31.5	32.6	34.8	37.8
Ismailia	28.5	31.2	32.4	34.7	30.3	32.8	33.3	35.9
Sharqia	29.7	30.4	34.4	30.9	33.5	33.8	35.1	38.0
Gharbia	29.2	32.4	33.9	31.1	32.9	29.9	35.2	38.4
Dakahlia	29.5	28.1	34.5	29.5	31.9	32.9	33.6	32.6
Monufia	29.0	28.0	34.3	29.7	32.3	32.8	34.8	37.4
Spring								
	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089
Alexandria	45.1	40.7	43.3	44.2	44.5	44.1	45.8	44.2
Beheira	45.3	41.7	43.5	45.4	44.5	45.2	44.7	45.8
Kafr El-sheikh	46.0	41.6	43.8	44.7	44.0	44.4	44.4	46.8
Ismailia	45.2	41.5	41.5	45.4	43.6	45.2	44.2	45.6
Sharqia	46.0	42.7	44.7	46.0	45.6	45.8	45.9	46.8
Gharbia	45.6	42.3	44.0	45.5	44.9	40.8	45.2	46.5
Dakahlia	46.5	42.8	44.9	45.4	45.1	45.3	44.5	44.7
Monufia	45.8	42.3	44.3	45.5	44.6	45.3	45.6	46.1
summer								
	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089
Alexandria	43.1	44.3	42.9	44.5	44.7	45.0	45.6	45.5
Beheira	44.1	44.8	44.6	44.3	44.8	47.0	46.4	45.8
Kafr El-sheikh	42.5	43.8	44.8	44.6	44.4	45.6	46.4	45.3
Ismailia	43.7	43.9	43.9	45.6	44.9	45.6	46.8	47.7
Sharqia	44.9	45.0	46.0	45.5	46.4	46.7	47.2	46.6
Gharbia	44.5	44.6	46.1	45.4	45.7	45.3	46.4	46.9
Dakahlia	44.2	45.1	45.6	45.2	46.6	46.6	48.8	49.9
Monufia	44.5	45.1	45.3	44.6	46.0	46.5	46.9	45.9
Autumn								
	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089
Alexandria	40.4	39.7	40.4	42.7	40.2	42.1	42.6	43.8
Beheira	40.6	41.6	40.8	43.0	41.1	43.1	43.7	43.5
Kafr El-sheikh	40.4	40.2	39.1	43.9	40.9	42.3	43.7	44.4
Ismailia	42.1	40.5	40.5	42.5	41.3	43.3	42.3	43.7
Sharqia	41.7	42.1	41.3	43.5	41.8	44.2	44.5	44.9
Gharbia	41.9	41.6	40.9	42.9	41.8	42.2	43.9	44.3
Dakahlia	41.2	41.4	40.4	44.1	41.3	43.8	47.0	45.4
Monufia	40.7	41.6	41.0	43.6	41.1	43.7	44.3	44.8

Table 4: Seasonal Minimum Minimum temperature for Lower Egypt governorates

winter								
	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089
Alexandria	2.4	3.2	4.5	3.6	4.0	5.2	5.0	4.2
Beheira	2.5	2.9	2.9	3.2	4.3	5.0	5.3	4.9
Kafr El-sheikh	2.9	4.4	3.4	4.1	4.1	4.5	5.9	5.7
Ismailia	1.3	1.1	0.4	1.7	2.0	2.2	2.7	2.7
Sharqia	1.4	1.9	2.2	1.9	1.8	3.0	4.0	3.8
Gharbia	1.4	1.2	1.5	2.7	2.1	1.0	2.6	3.4
Dakahlia	1.2	2.0	2.1	1.3	1.4	2.5	1.9	2.2
Monufia	1.1	2.2	1.7	1.5	1.9	2.8	3.3	3.9
Spring								
	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089
Alexandria	6.2	6.2	6.7	7.4	5.3	7.4	6.4	6.3
Beheira	6.3	5.1	7.4	6.8	5.6	7.5	7.4	8.1
Kafr El-sheikh	6.9	6.1	8.3	7.7	7.5	8.4	8.1	9.1
Ismailia	4.4	2.8	4.6	5.0	3.6	4.7	4.6	5.4
Sharqia	4.1	4.9	5.6	6.6	4.4	6.0	6.2	6.9
Gharbia	4.5	4.4	5.5	6.5	4.1	2.8	5.9	7.0
Dakahlia	4.5	4.8	5.8	6.5	5.1	6.4	5.7	6.7
Monufia	4.1	4.2	5.1	6.2	4.4	6.0	5.7	6.5
summer								
	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089
Alexandria	18.3	18.1	18.0	17.8	18.6	18.3	18.2	19.2
Beheira	19.4	19.8	19.0	19.9	18.8	20.1	19.7	20.7
Kafr El-sheikh	18.0	17.7	19.1	17.9	19.0	19.5	19.2	20.0
Ismailia	16.4	17.2	16.4	15.7	17.0	17.5	17.4	18.4
Sharqia	17.5	18.7	18.9	18.5	18.9	19.5	18.9	20.1
Gharbia	19.1	18.9	18.5	18.1	18.8	16.2	18.8	20.2
Dakahlia	17.4	17.9	18.7	17.5	18.5	18.8	18.9	21.4
Monufia	17.6	17.9	17.5	17.8	18.1	18.4	18.0	19.1
Autumn								
	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089
Alexandria	7.2	8.6	9.2	9.7	10.8	11.1	10.6	11.7
Beheira	7.3	8.7	8.3	9.2	10.5	9.6	9.4	11.6
Kafr El-sheikh	8.3	10.1	10.6	11.2	11.9	11.7	11.1	12.7
Ismailia	6.6	7.5	7.1	6.9	8.5	9.4	6.4	10.5
Sharqia	7.2	9.0	7.7	9.1	10.3	10.9	9.4	11.7
Gharbia	6.7	8.6	7.7	8.6	9.9	8.0	9.0	11.6
Dakahlia	6.7	8.4	8.2	9.1	10.3	10.3	6.9	10.3
Monufia	6.9	8.5	7.3	8.8	9.9	10.7	8.4	11.4

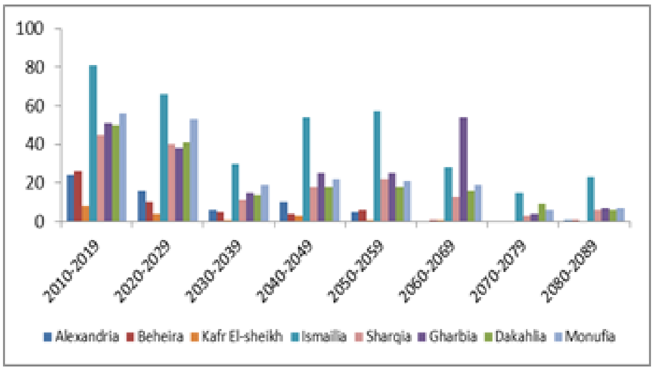

Figure 1: Number of Frost days in Lower Egypt

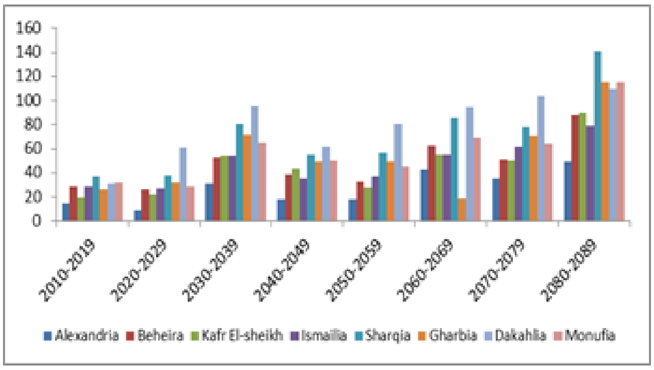

Figure 2: Number of summer days in Lower Egypt

B. Middle Egypt Governorates

TXx and TNn in Middle Egypt governorates (Giza, Beni Suef, Faiyum, and Minya) are shown in tables (5, and 6), and it's observed that all studied Middle Egypt governorates find the highest TXx value in summer season will be during the period 2060-2069 except at Minya, its highest value will be during 2070-2079. While in the autumn season, the highest TXx will be during the period 2070-2079, but in winter and spring season will be during the period 2080-2089.

Table 6 shows the values of TNn of studied Middle Egypt governorates each 10 years from 2010 up to 2089, and it's observed that all governorates agreed in the period which has the lowest value in each season where in winter and autumn, the period 2010-2019 had the lowest value of TNn, 2020-2029 in spring season, and 2050-2059 in summer season.

Figure (3) shows the number of frost days in middle Egypt governorates during the period 2010-2090, and it's observed that the highest number of frost days was in 2010 decade while the lowest number was in 2070 decade at all studied governorates except at Minya, its lowest record was in 2060 decade.

The number of summer days in winter season at middle Egypt governorates is shown in figure (4), and it's observed that the decade 2080 has the highest number of summer days, while the lowest one was ranged between 2010 and 2020 decades with very close values, except at Minya, where its lowest number was in 2060 decade.

Table 5: Seasonal Maximum Maximum temperature for Middle Egypt governorates

	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089
winter								
Giza	28.5	28.6	34.0	29.4	32.0	32.8	34.0	36.9
Beni Suef	28.0	29.4	33.8	30.4	31.2	32.7	33.6	36.5
Faiyum	27.8	28.2	33.4	29.2	30.8	32.1	33.3	36.0
Minya	28.4	30.8	32.9	29.9	30.0	27.9	33.7	35.8
Spring								
Giza	45.3	41.7	43.5	45.4	44.5	45.2	44.7	45.8
Beni Suef	44.6	42.4	42.4	44.9	44.7	44.2	43.7	45.0
Faiyum	44.3	41.9	42.4	44.6	44.1	43.8	43.6	44.7
Minya	44.7	42.1	42.2	44.6	44.1	36.1	43.8	44.9
summer								
Giza	44.1	44.8	44.6	44.3	44.8	47.0	46.4	45.8
Beni Suef	43.5	43.8	43.8	44.3	44.2	47.1	46.2	46.5
Faiyum	43.4	44.1	43.9	43.7	44.0	47.1	45.8	46.0
Minya	44.1	43.9	44.1	44.2	44.4	39.7	46.3	45.8
Autumn								
Giza	40.6	41.6	40.8	43.0	41.1	43.1	43.7	43.5
Beni Suef	40.2	41.6	40.7	42.8	40.9	42.7	43.4	42.8
Faiyum	39.9	41.1	40.4	42.6	40.8	42.3	43.4	42.7
Minya	40.4	41.7	41.0	42.7	40.8	37.3	43.5	42.5

Table 6: Seasonal Minimum Minimum temperature for Middle Egypt governorates

	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089
winter								
Giza	2.5	2.9	2.9	3.2	4.3	5.0	5.3	4.9
Beni Suef	0.4	1.0	0.6	1.4	1.7	3.2	3.1	2.7
Faiyum	1.4	1.8	1.6	2.4	3.0	4.1	3.8	3.7
Minya	1.7	2.2	2.1	2.4	3.1	7.2	3.9	3.5
Spring								
Giza	6.3	5.1	7.4	6.8	5.6	7.5	7.4	8.1
Beni Suef	4.4	2.6	4.8	4.5	3.6	5.4	5.2	4.9
Faiyum	5.0	3.2	5.2	5.3	4.2	5.9	5.8	6.7
Minya	4.4	3.7	5.4	5.0	5.2	12.4	5.8	5.8
summer								
Giza	21.0	19.8	19.0	19.9	18.8	20.1	19.7	20.7
Beni Suef	18.8	18.8	17.3	17.9	16.9	19.0	18.1	18.4
Faiyum	18.4	18.5	17.4	18.0	16.7	19.1	18.0	18.7
Minya	19.9	19.8	19.5	19.8	18.2	23.0	19.7	20.1
Autumn								
Giza	7.3	8.7	8.3	9.2	10.5	9.6	9.4	11.6
Beni Suef	3.9	6.7	6.6	6.6	8.3	8.3	7.1	9.3
Faiyum	5.8	7.6	7.4	7.6	9.1	8.7	8.0	10.2
Minya	4.5	7.3	7.9	7.2	9.3	16.7	7.6	9.4

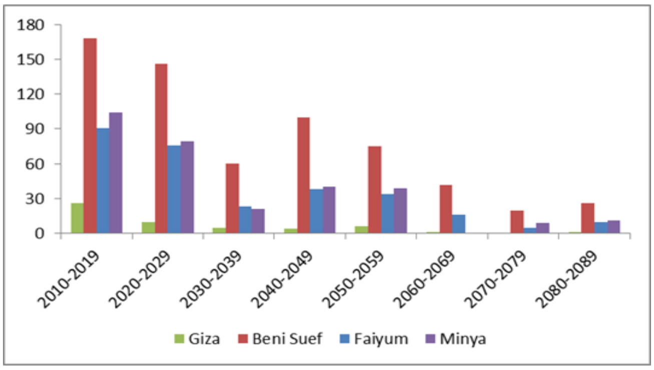

Figure 3: Number of Frost days in Middle Egypt governorates

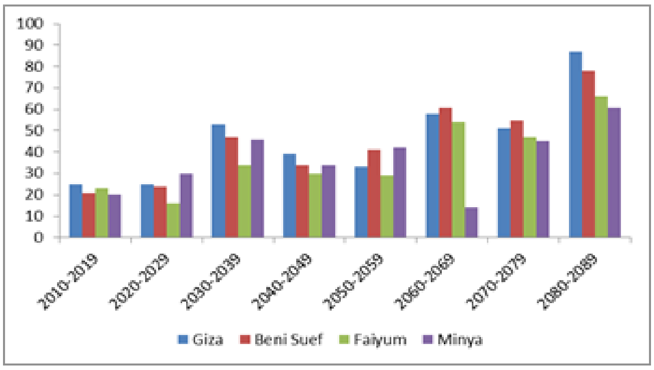

Figure 4: Number of summer days in Middle Egypt governorates

C. Upper Egypt Governorates

TXx and TNn in Upper Egypt governorates (Asyut, Sohag, Qena, and Aswan) are shown in tables (7, and 8), and it's observed that all studied Upper Egypt governorates agreed that, the highest TXx value in spring season was during the period 2040-2049, and during the period 2070-2079 in the autumn season. While in the winter season, the highest TXx values were observed during the period 2070-2079 at Qena and Aswan, and during the 2080-2089 at Asyut and Sohag. In the summer season, Sohag and Qena demonstrated that the period 2060-2069 has the highest TXx, while Asyut and Aswan find the highest TXx during the period 2070-2079.

Table (8) shows the values of TNn at Upper Egypt governorates, and it's observed that in the winter and autumn seasons all Upper Egypt governorates find the period 2010-2019 has the lowest TNn except at Asyut in winter and Aswan in autumn, where it was during 2070-2079 in both of them, but in the summer season the lowest TNn was observed during the period 2050-2059 while in the spring season was observed during the period 2020-2029 except at Asyut where it was observed during the period 2010-2019.

Figure (5) shows the number of frost days in Upper Egypt governorates during the period from 2010 up to 2089, and it's observed that the highest number of frost days was in 2010 decade while the lowest number was in 2080 decade at all studied governorates except at Asyut, it was in 2070 decade.

The number of summer days in winter season at Upper Egypt governorates is shown in figure (6) and it's observed that similar to Lower and middle Egypt observations, the decade 2080 has the highest number of summer days, while the lowest one was in 2010 decade except at Aswan, there is observed unexpected decrease in 2050 decade.

Table 7: Seasonal Maximum Maximum temperature for Upper Egypt governorates

	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089
Winter								
Asyut	30.6	31.2	33.3	32.4	30.6	33.4	34.1	35.9
Sohag	31.5	32.7	33.9	33.3	32.2	35.0	35.4	36.4
Qena	32.2	34.1	34.3	34.5	33.4	34.7	36.2	36.0
Aswan	35.7	35.3	36.5	35.5	31.5	36.1	38.2	36.9
Spring								
Asyut	44.2	42.2	43.5	44.9	43.2	43.8	44.4	43.9
Sohag	43.8	42.3	44.1	45.4	43.8	44.8	44.6	44.9
Qena	43.2	41.8	43.6	45.1	44.5	44.6	44.0	45.0
Aswan	44.4	44.2	43.8	46.6	44.1	45.1	45.3	45.7
Summer								
Asyut	43.7	43.4	44.4	44.0	45.0	45.9	46.0	45.8
Sohag	44.5	44.3	46.0	46.3	46.4	47.3	47.0	47.2
Qena	45.0	46.1	47.2	46.3	47.7	48.5	46.9	47.4
Aswan	45.3	46.9	46.9	46.8	44.4	47.8	47.9	47.7
Autumn								
Asyut	40.7	42.4	40.8	43.4	40.6	41.3	44.3	42.4
Sohag	41.4	43.8	41.6	44.5	40.9	42.9	45.7	42.8
Qena	41.4	43.5	42.5	45.0	41.9	43.6	46.2	43.2
Aswan	42.1	42.1	43.8	44.8	40.8	45.3	46.9	44.5

Table 8: Seasonal Minimum Minimum temperature for Upper Egypt governorates

	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089
Winter								
Asyut	0.6	1.6	1.0	1.8	2.5	2.1	0.0	2.9
Sohag	0.4	2.2	1.9	2.8	2.3	2.3	3.4	3.4
Qena	-0.7	0.5	1.3	1.2	0.4	1.6	2.0	1.8
Aswan	1.6	2.6	4.0	1.8	3.1	3.8	4.7	3.8
Spring								
Asyut	3.1	3.2	4.6	3.3	5.3	5.0	5.1	6.0
Sohag	3.2	2.8	5.1	4.7	6.0	6.4	5.3	5.9
Qena	2.6	1.7	3.0	3.2	3.5	4.6	3.2	4.2
Aswan	6.5	5.1	6.2	5.8	5.2	7.6	6.1	7.2
Summer								
Asyut	19.8	20.1	20.2	20.4	18.6	21.1	20.1	20.0
Sohag	19.5	20.2	20.2	21.3	18.3	21.5	20.5	21.0
Qena	17.3	18.3	18.3	19.5	17.2	20.6	18.9	19.1
Aswan	20.1	20.9	21.2	22.0	18.2	21.7	21.8	23.2
Autumn								
Asyut	3.8	6.5	7.7	7.1	8.8	9.0	11.1	9.6
Sohag	4.7	6.6	7.2	7.5	9.7	9.4	7.6	9.7
Qena	3.9	5.1	5.5	6.1	8.0	8.5	5.8	7.6
Aswan	3.8	6.5	7.7	7.1	8.8	9.0	0.0	9.6

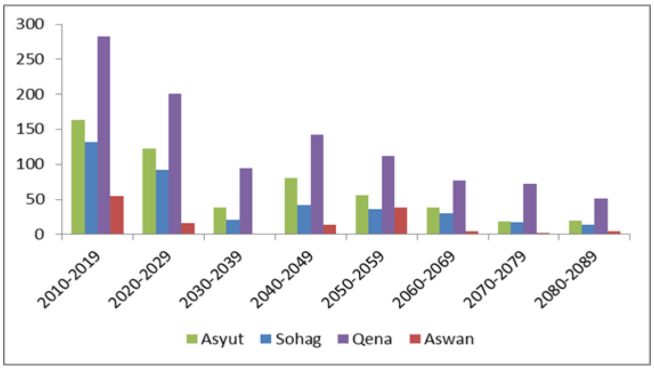

Figure 5: Number of Frost days in Upper Egypt governorates.

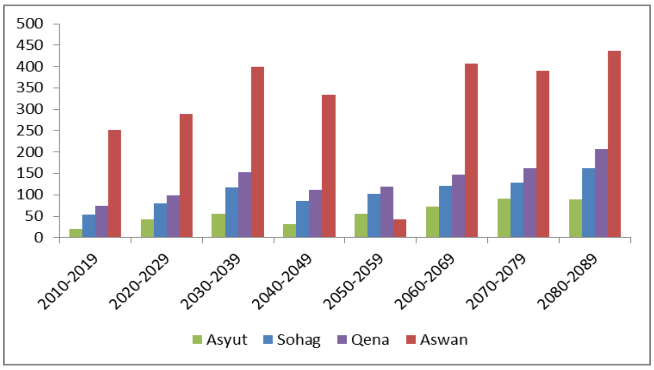

Figure 6: Number of summer days in Upper Egypt governorates.

One regional study focused on changes in temperature extremes over the Middle East region (Zhang et al., 2005), which is part of the investigated study area. This study reported consistent also changes towards warmer and less cold extremes in this region. In addition to this study, there have been some local analyses focusing on Libya and Tunisia, for example, (El Kenawy et al., 2009; El Fadli, 2012) reported regional warming trends stations in Libya, and Tunisia (Dahech and Beltrando, 2012). Driouech et al. (2010) documented a reduction in precipitation over the period 1958-2000 in the Moulouya watershed in Morocco. Model simulations of climate extremes in the Arab region during the historical period show similar warming trends over the past century (Sillmann et al., 2013a), and these trends continue in multi-model future climate projections (Sillmann et al., 2013b). The signal in extreme precipitation projections is incoherent; however, there is a tendency towards drying. Projections of changes in the nearby Mediterranean region point to a warming trend with more frequent extreme warm events (Giorgi and Lionello, 2008). (Donat et al, 2014) studied the temporal changes in climate extremes in the Arab region since the middle of the 20th Century and found that, warming trends are generally stronger during the most recent 30 years (since 1981) than for the longer period (since 1966). This is also confirmed by the region-averaged time series, which show that most of the warming has happened since the early 1970s. Studying the occurrence of extreme precipitation is characterized by much stronger temporal and spatial variability than seen in the temperature extremes. Also IPCC AR5 (Niang et al., 2014) reported that, in northern Africa, the northwestern Sahara experienced 40 to 50 days of heat wave per year during the 1989–2009 time period (Vizy and Cook, 2012), and there is an expected increase in this number of heat wave days over the 21st century (Patricola and Cook, 2010; Vizy and Cook, 2012), and reduction in rainfall over northern Africa is very likely by the end of the 21st century.

IV. Conclusion

In general, this paper presents an analysis of temperature extremes in different three climatic regions in Egypt, and their changes during the period 2010 up to 2099. The results give evidence for significant changes in the temperature extremes occurrence during the next eight decades. The Highest TXx was observed during the period 2080-2089 while lowest TNn was observed during the period 2010-2019 in the most of Egypt governorates. Also, it has been observed that the maximum number of frost days was observed in 2010 decade while the maximum number of summer days in winter season was observed in 2080 decade at most of Egypt governorates.

V. Acknowledgement

We would like to express our gratitude towards the project of "Regional climate change database for the agriculture sector in Egypt" which funded by Science & Technology Development Fund (STDF) for supporting this research.

VI. REFERENCES

[1]. Alexander LV, Zhang X, Peterson TC, Caesar J, Gleason B, Klein Tank AMG, Haylock M, Collins D, Trewin B, Rahim F, Tagipour A, Kumar Kolli R, Revadekar JV, Griffiths G, Vincent L, Stephenson DB, Burn J, Aguilar E, Brunet M, Taylor M, New M, Zhai P, Rusticucci M, Vazquez Aguirre JL. 2006. Global observed changes in daily climate extremes of temperature and precipitation. Journal of Geophysical Research-Atmospheres 111: D05109. DOI: 10.1029/2005JD006290

[2]. Alexandera, L. and Tebaldi, C. (2012). Chapter 10 of The Future of the World's Climate, 2nd Edition: Climate and Weather Extremes: Observations, Modelling, and Projections. Pages 253-288.

[3]. Dahech S, Beltrando G. 2012. Observed temperature evolution in the City of Sfax (Middle Eastern Tunisia) for the period 1950–2007. Climatic Change. 114(3-4): 689–706. DOI: 10.1007/s10584-012- 0420-x.

[4]. Driouech F, Mah´e G, D´equ´e M, Dieulin C, El Heirech T, Milano M, Benabdelfadel A, Rouche N. 2010. Evaluation d'impacts potentiels de changements climatiques sur l'hydrologie du bassin versant de la Moulouya au Maroc. Global Change: Facing Risks and Threats to Water Resources (Proc. of the Sixth World FRIEND Conference, Fez, Morocco, October 2010). IAHS Publ. 340, 2010.

[5]. Donat, M. G; T. C. Peterson, M. Brunet, A. D. King, M. Almazroui, R. K. Kolli, Djamel Boucherf, Anwar Yousuf Al-Mulla, Abdourahman Youssouf Nour, Ahmed Attia Aly, Tamer Ali Ali Nada, Muhammad M. Semawi, Hasan Abdullah Al Dashti, Tarek G. Salhab, Khalid I. El Fadli, Mohamed K. Muftah, Sidaty Dah Eida, Wafae Badi, Fatima Driouech, Khalid El Rhaz, Mohammed J. Y. Abubaker, Ayman S. Ghulam, Amani Sanhouri Erayah, Maher Ben Mansour, Waleed O. Alabdouli, Jemie Salem Al Dhanhani, and Majed N. Al Shekaili. 2014. Changes in extreme temperature and precipitation in the Arab region: long-term trends and variability related to ENSO and NAO. INTERNATIONAL JOURNAL OF CLIMATOLOGY Int. J. Climatol. 34: 581–592 (2014) Published online 6 May 2013 in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/joc.3707

[6]. El-Fadli KI. 2012. Climate change over Libya and impacts on agriculture. Thesis submitted for the degree of MSc in Meteorology, Cairo University, Cairo, p. 107.

[7]. El-Kenawy A, L'opez-Moreno J, Vicente-Serrano S, Mekld M. 2009. Temperature trends in Libya over the second half of the 20th century. Theoretical and Applied Climatology 98: 1–8.

[8]. Giorgi, F. and P. Lionello, 2008: Climate change projections for the Mediterranean region. Global and Planetary Change 63: 90–104. DOI: 10.1016/j.gloplacha.2007.09.005.

[9]. Kerr, R., 2013: In the hot seat. Science, 342, 688–689.

[10]. Khalil A.A. and Hassanein M. K., 2016. Extreme weather events and negative impacts on Egyptian agriculture. Int. J. Adv. Res. 4(12), 1843-1851.

[11]. Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham, and P. Urquhart, 2014: Africa. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1199-1265.

[12]. Patricola, C.M. and K.H. Cook, 2010: Northern African climate at the end of the twenty-first century: an integrated application of regional and global climate models. Climate Dynamics, 35(1), 193-212.

[13]. Paula j. Brown, Raymond S. Bradley and frank T. Keimig, 2010. Changes in Extreme Climate Indices for the Northeastern United States, 1870–2005. Journal of Climate, Vol. 23, 6555-6572.

[14]. Peterson TC, Manton MJ. 2008. Monitoring changes in climate extremes: a tale of international collaboration. Bulletin of the

American Meteorological Society 89: 1266–1271. DOI: 10.1175/ 2008BAMS2501.1.

[15]. Sillmann J, Kharin VV, Zwiers FW, Zhang X, Bronaugh D. 2013a. Climate extremes indices in the CMIP5 multi-model ensemble. Part 1: model evaluation in the present climate. Journal of Geophysical Research-Atmospheres 118(4): 1716–1733. DOI: 10.1002/jgrd.50203.

[16]. Sillmann J, Kharin VV, Zwiers FW, Zhang X, Bronaugh D. 2013b. Climate extremes indices in the CMIP5 multi-model ensemble. Part 2: future projections. Journal of Geophysical Research-Atmospheres. DOI: 10.1002/jgrd.50188.

[17]. Stephanie C. Herring, Martin P. Hoerling, Thomas C. Peterson, and Peter A. Stott, 2014. Explaining extreme events of 2013 from a climate perspective. Special Supplement to the Bulletin of the American Meteorological Society, Vol. 95, No. 9, September 2014.

[18]. Stocker, T. F., and Coauthors, Eds., 2014: Climate Change 2013: The Physical Science Basis. Cambridge University Press, 1535 pp.

[19]. Tubiello FN, Soussana J-F, Howden SM (2007). Crop and pasture response to climate change. PNAS 104 (50):19686–19690.

[20]. United Nations and League of Arab States report, 2015. Climate Projections and Extreme Climate Indices for the Arab Region. Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR). Publication issued by ESCWA.

[21]. Vizy, E.K. and K.H. Cook, 2012: Mid-twenty-first-century changes in extreme events over northern and tropical Africa. Journal of Climate, 25(17), 5748-5767.

[22]. Zhang XB, Aguilar E, Sensoy S, Melkonyan H, Tagiyeva U, Ahmed N, Kutaladze N, Rahimzadeh F, Taghipour A, Hantosh TH, Albert P, Semawi M, Ali MK, Al-Shabibi MHS, Al-Oulan Z, Zatari T, Khelet IA, Hamoud S, Sagir R, Demircan M, Eken M, Adiguzel M, Alexander L, Peterson TC, Wallis T. 2005. Trends in Middle East climate extreme indices from 1950 to 2003. Journal of Geophysical Research-Atmospheres 110: D22104. DOI: 10.1029/2005jd006181.