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Assessment of Extreme Climate Indices Over Libya and Its Relationship to Mortality

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ABSTRACT

The main objective of this paper was to assess the variation of the different extreme climate indices over Libya from different CMIP5 models driven by different emission scenarios. Spatiotemporal variability of extreme indices was assessed for the near future period 2020-2070 which were compared to a base period 1961-1990. The results showed that there were significant trends for minimum temperature indices such as the percentage of TN10p and TX10p reaching up to 10 % by the end of 2070. For maximum temperature indices such as the percentage of TN90p and TX90p, there was a significant increase compared to the base period by 50% at the end of 2070. For precipitation, an insignificant difference was found when compared to the historical references. Also, form CORDEX models, extreme temperature indices were calculated for four stations for the near future period (2021-2055). The results for stations Sebha, Kufra, Tripoli and Shahat, had a significant increase of TX90p and TN90p, and a significant negative trend for TX10p and TN10p. The number and duration of heat waves had a positive trend for all the stations except for Kufra and Shahat which had a negative trend for the heat wave numbers. Thus, these results have been vital for special concerns regarding the effects on human health and mortality ratio.

Keywords: *Climate, Extreme, Indices, CMIP5, CORDEX, Libya, Development.*

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1. INTRODUCTION

Libya facades major problems in adapting to climate change. It has been evaluated that one third of the residents live under the scarcity line, and therefore have inadequate resources to acclimatize to predictable increases in temperature and extreme weather indices. Above 85 % of the inhabitants live in urban areas, commonly near the coastline, somewhere water is more available. Extreme weather has serious impacts on many different sectors such as community, and surrounding environment which led to economy loss (IPCC, 2007). Therefore, an early step for studies including the climate change influence is the investigation of extreme indices (Sharma and Babel, 2013). Many studies, such as Santos and Oliveira (2017), Gamal (2017), Jiang et al (2016), Soltani et al (2015), Almazroui et al (2014), Athar (2013), have revealed that there have been significant changes in some climate indices which have taken place all over the world. So, it is essential to have a well understanding about the behavior of some climate variables in local scale.

ETCCDMI which is The Expert Team on Climate Change Detection, Monitoring and Indices, funded by WMO (World Meteorological Organization) Commission for Climatology (CCI) and the Climate Variability and Predictability Project (CLIVAR) has established a set of indices that characterizes a public guide for regional analysis of climate. The indices define specific features of extremes, containing frequency, amplitude and persistence. The core set comprises 27 extremes indices for temperature and precipitation (Klein Tank et al., 2009; Alexander et al., 2006; Zhang et al., 2011).

2. TARGET AREA AND DATA

The target area was Libya which is located on the northern part of Africa (Figure 1), and surrounded by the Mediterranean Sea to the north, Egypt to the east, Sudan to the southeast, Chad and Niger to the south, and Algeria and Tunisia to the west. Libya has an area of 1.8 million km2.

Figure 1: map of Libya,
https://www.britannica.com/place/Libya

The climate extremes indices with definitions are given in table 1, which were calculated for number of global climate models participating in the Coupled Model Inter comparison Project Phase 5 (CMIP5) listed in table 2. The validation of these indices and the analysis of their predictable future fluctuations simulated by the CMIP5 models is obtainable in Sillmann et al. (2013a, 2013b).

This paper has two parts, the first part reviews the extreme climate indices over Libya from multi model ensemble mean from CMIP5 under different scenarios of RCP45 and RCP85. And the second part, in which high resolution daily data of CORDEX regional climate models was used to calculate extreme temperature indices over selected four stations, two inland stations (Sebha and Kufra), and two coastal stations (Tripoli and Shahat) in Libya for the near future period 2021-2055. Only results for Tripoli and Kufra have been presented here.

Table 1. used extreme climate indices as defined by ETCCDMI

ID	Indicator Name	Definitions	UNIT
TR20	Tropical nights	Annual count when TN(daily minimum)>20ºC	Days
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
R95p	Very wet days	Annual total PRCP when RR>95th percentile	mm
PRCPTOT	Annual total wet- day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm

Table 2. The state of art CMIP5 GCM models and their attributes, https://portal.enes.org/data/enes-model-data/cmip5/resolution

CMIP5 model ID	Institute and Country of the model	Horizontal resolution (lat.*lon)
ACCESS1.0	Commonwealth Scientific and Industrial Research Organization (CSIRO)	1.9*1.2
BCC-CSM1.1	Beijing Climate Center, China Meteorological Administration, BCC	2.8*2.8
CanESM2	Canadian Centre for Climate Modelling and Analysis, CCCMA	2.8*2.8
CMCC-CM	Centro Euro-Mediterraneo per I CambiamentiClimatici, CMCC	0.7*0.7
CMCC-CMS		1.9*1.9
CNRM-CM5	Centre National de Recherches Météorologiques, CNRM	1.4*1.4
CSIRO-Mk3.6.0	Commonwealth Scientific and Industrial Research Organization	1.9*1.9
GFDL-ESM2G	NOAA Geophysical Fluid Dynamics Laboratory, NOAA GFDL	2.5*2.0
GFDL-ESM2M		2.5*2.0
HadGEM2-CC	Met Office Hadley Centre, MOHC	1.9*1.2
HadGEM2-ES		1.9*1.2
INM	Institute for Numerical Mathematics, Russia	2.0*1.5
IPSL-CM5A-LR	Institute Pierre-Simon Laplace, IPSL	2.5*1.3
IPSL-CM5B-LR		3.7*1.9
MIROC5	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies, MIROC	1.4*1.4
MIROC-ESM		2.8*2.8
MIROC-ESM-CHEM		2.8*2.8
MPI-ESM-MR	Max Planck Institute for Meteorology, Germany	1.9*1.9
MPI-ESM-LR		1.9*1.9
MRI-CGCM3	Meteorological Research Institute, MRI, South Korea	1.1*1.1
NorESM1-M	Norwegian Climate Centre, NCC	2.5*1.9

3. RESULTS AND DISCUSSION

Spatial variation of warm days and nights:

As shown in Figure (2), there was a significant increase in the percentage of warm days (TX90p) and nights (TN90p) numbers at the near future (2020-2070) comparing to the base period 1961-1990. It was clear that the main increases were found at the coastal area up to 40 % at both scenarios. The trend of TX90p and TN90p has been represented in Figure 3, which shows that Libya would experience a significant increase of these indices in the near future.

Spatial variation of cold days and nights:

Unlike TN90p and TX90p, a negative spatial variation was found for cold days' TX10p and nights' TN10p indices, Figure (3), this referred to more frequent tropical nights and heat waves over Libya which have many impacts on different sectors such as health and energy. This variation appeared more at the mean trend of TX10p and TN10p as shown in Figure 3, which reflected the significant negative trend, but for tropical night parameter (TR) there was a significant increase in the number of days of TR which was a result of a change happened to TN10p and TN90p.

Extreme temperature indices from CORDEX regional climate models:

In this part, high resolution regional climate models CORDEX (Giorgi et al., 2009) were used to assess the extreme climate indices for 4 stations which were Sebha, Kufra, Shahat and Tripoli as listed in table 3. The information about the two CORDEX regional climate models used can be found in table 4, also the daily data of minimum and maximum temperatures can be downloaded through this link http://esgf-node.dkrz.de/.

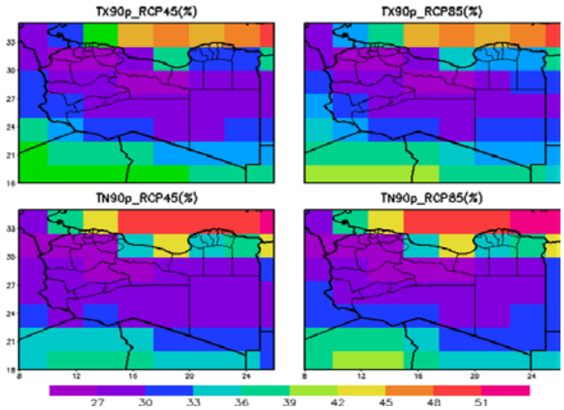

Figure 2. The spatial variation of mean ensemble CMIP5 models for RCP45 and RCP85, (a) TX90p at RCP45 and (b) TX90p at RCP85, (c) TN90p_RCP45 and (d) is TN90p_RCP85.

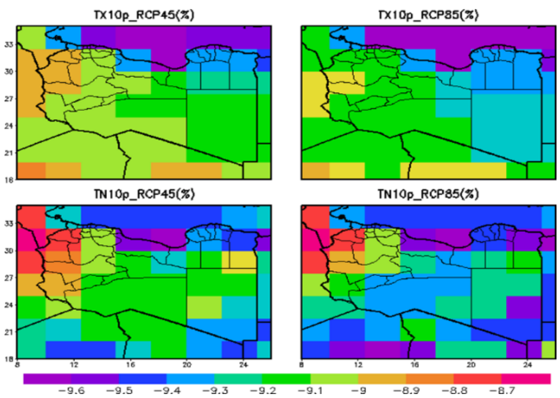

Figure 3. The spatial variation of mean ensemble CMIP5 models for RCP45 and RCP85, (a) TX10p at RCP45 and (b) TX10p at RCP85, (c) TN10p_RCP45 and (d) is TN10p_RCP85

Table 3. Libya's four stations used in this part

WMO ID	Station name	Latitude	Longitude	Elevation
62124	Sebha	27.02	14.45	432
62271	Kufra	24.22	23.3	436
62010	Tripoli	32.67	13.15	81
62056	Shahat	32.8	21.88	648

EQ1

$$MAE = \frac{1}{n}\sum_{j=1}^{n}|y_j - \hat{y}_j|$$

From Figure (4-a, b), it can be found that SMHI and UQAM driven by two different boundary conditions can reproduce the mean climatology of TX and TN. A cold bias can be observed for TX annual variability especially in summer seasons shown in Figure (3, a), while for TN, a warm bias in summer season was found.

Table 4: contains information about CORDEX model used in this paper

Acronym	Center of research	RCM	References
SMHI-RCA35	SverigesMeteorologiskaochHydrologiskaInstitut (Sweden)	RCA35	Samuelsson et al. (2011)
UQAM-CRCM5	Université du Québec à Montréal (Canada)	CRCM5	Zadra et al., (2008), Hernandez-Diaz et al. (2013)

Mean absolute error (MAE) was calculated to assess the impact of boundary condition in CORDEX models. As shown in Figure 6, which explains the results of MAE for each model corresponding to CRU data. It has been clear that GCM MPI has a good boundary condition to represent minimum and maximum temperatures for SMHI regional climate model, so SMHI regional climate model driven by MPI GCM model was used to assess the near future variability (2021-2055) of extreme temperature indices for selected four stations and RCP45 scenario.

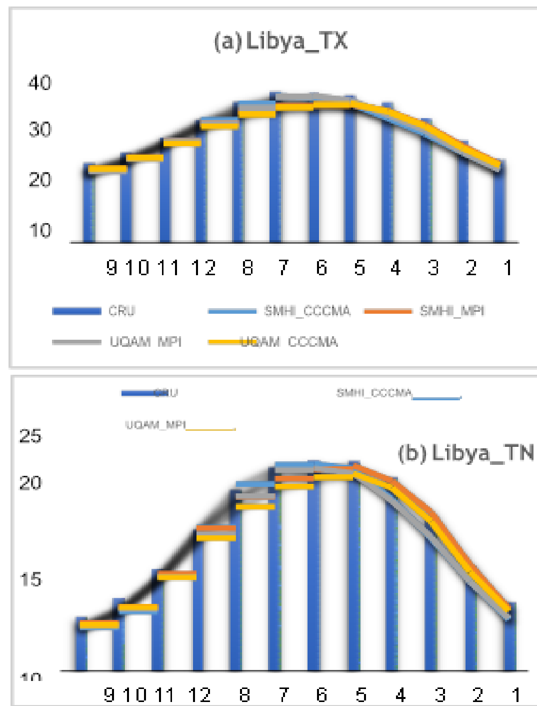

Figure 4: annual variability of CRU, SMHI_MPI, SMHI_CCCMA, UQAM_MPI and UQAM_CCCMA, (a) for maximum temperature and (b) for minimum temperature

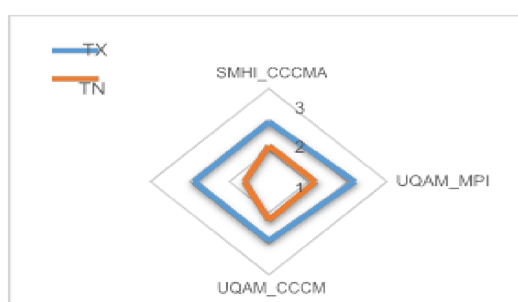

Figure 5: Mean Absolute error for SMHI_MPI, SMHI_CCCMA, UQAM_MPI and UQAM_CCCMA, (blue line) for maximum temperature and (red line) for minimum temperature

Extreme climate indices by CORDEX models

Daily data for TX and TN for SMHI-MPI model under RCP45 future scenario for the near future period 2021-2055 was used to calculate extreme temperature indices for selected stations by CLIMPACT2 R-Package. Ten extreme temperature indices were calculated by CLIMPACT2, which is a free package and can be downloaded through this link https://github.com/ ARCCSS-extremes/climpact2 , Which are warm spell duration index (WSDI), cold spell duration index (CSDI), TX10p, TX90p, TN10p, TN90p, summer day (SU), tropical night (TR) and heat wave number and duration.

Temporal analysis of hot (TX90p) and cold days (TX10p):

Figure (6, a, b) shows the time series of TX90p and TX10p for the current and near future time. All the stations exhibited a significant increase in TX90p at Sebha, Figure (7, a) the trend value of TX90p increase from 0.04%/year to 0.25%/year for the future period (2021-2055) and the amounts for Kufra, Tripoli, and Shahat were (0.26%/yr), (0.25%/yr) (0.23%/yr); respectively.

For cold days' indicator (TX10p), all the stations had a significant negative trend. For Sebha, the present and future trend of TX10p was (-0.06%/yr), while for Kufra, it was -0.11%/yr and -0.06%/yr for the present and future periods, respectively. For Tripoli, the trend was -0.07%/yr and -0.02%/yr for the near future period. For Shahat as shown in Figure (8, d), the trend for the current period was -0.06%/yr and -0.03 for the period (2021- 2055).

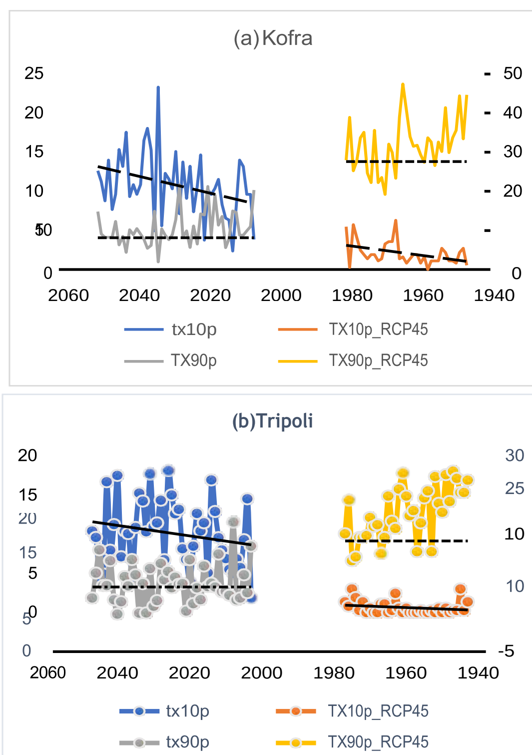

Figure 6: warm days' index (TX90p) and cold days' index (TX10p) for the present and future period (2021- 2055), (a) Kufra, (b) Tripoli

Temporal analysis of hot (TN90p) and cold nights (TN10p):

As shown in Figure (7, a, b), it was probable to find predominant positive trends with statistical meaning in all the stations for warm nights TN90p and statistical significance of decreasing for cold nights TN10p. For station Sebha, it could be observed that the trend TN90p was 0.12%/yr and 0.24%/yr for the present and future periods, respectively. The more frequent increase in the percentage of the warm nights was found in stations Tripoli and Shahat which had a trend of 0.1%/yr for current and 0.81%/yr for the near future period. It was clear that the trend of TN90p at coastal stations Tripoli and Shahat was higher than the trend at the inland stations such as Sebha and Kufra.

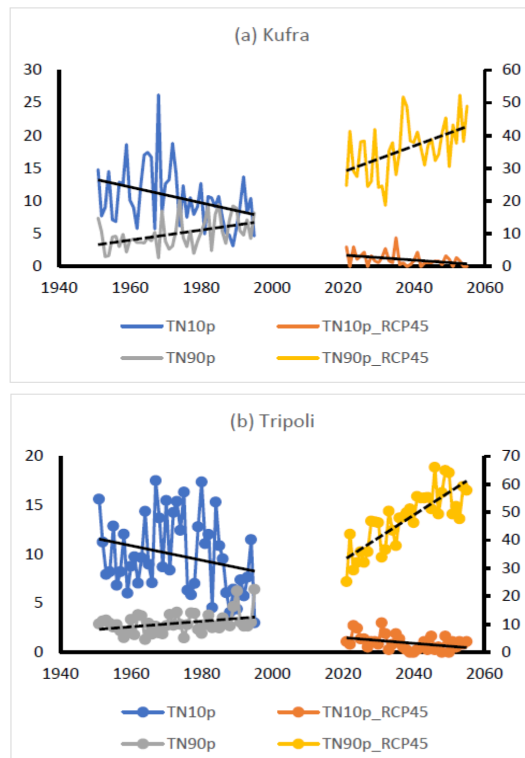

Figure 7. Warm nights' index (TN90p) and cold nights' index (TN10p) for the present and future periods (2021- 2055), (a) Kufra, (b) Tripoli

Temporal analysis of HWN and HWD:

Figure (8, a, b) explains the annual variation of heat wave number HWN and heat wave duration HWD. A statistically significant positive trend for HWD was observed in all the stations. For 9, a at Sebha, the trend value was 0.1 day/yr for the current and future periods. For Kufra, there was a large increase from 0.11day/yr to 0.95day/tr. For Tripoli, the trend was 0.04day/yr and 0.3day/yr while for the coastal station Shahat at the east, the trend was 0.05day/yr and 1.5day/yr. For heat wave number HWN, an opposite signal of climate change was observed. At coastal region, a decrease was found at the future trend of HWN -0.05day/yr for Shahat station while there was a positive trend at Tripoli station by 0.06day/yr. For inland stations, Sebha and Kufra. Sebha had an increase in HWN by 0.03day/yr, and Kufra had a negative trend by-0.04day/yr.

The values of trend for each extreme climate indicator have been summarized in table 5., which all the indicator had a significant increasing trend except the indicator of percentage of cold (TN10p) and warm (TN90) nights. All the values were statistically significant at 0.05 level.

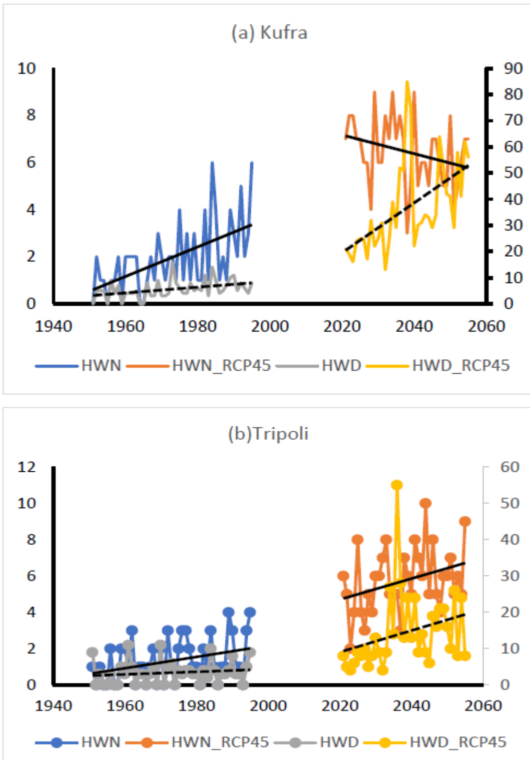

Figure 8: Heat wave number (HWN) and Heat wave duration (HWD) for the present and future periods (2021-2055), (a) Kufra, (b) Tripoli.

Table 5. The trend value of extreme indices indicator as calculated by CLIMPACT2.

Indicator	Tripoli	Shahat	Sebha	Kufra
WSDI	0.24	0.71	0.59	0.91
CSDI	-0.05	-0.04	-0.04	-0.06
TR>20 C	0.54	0.69	0.68	0.82
SU> 25 C	0.66	0.82	0.22	0.25
TX10p	-0.14	-0.13	-0.12	-0.13
TX90p	0.16	0.26	0.24	0.31
TN10p	-0.13	-0.13	-0.13	-0.14
TN90p	0.54	0.62	0.26	0.38
HWN	0.06	0.03	0.06	0.06
HWD	0.15	0.86	0.22	0.47
TXge35	0.05	0.02	0.54	0.54
TXge40	-	-	0.68	0.75

Extreme climate indices and Health

Worldwide climate change will be complemented by an amplified occurrence and strength of heat waves, as well as stove summers and milder winters. Projected modelling studies, by climate scenarios, have assessed future temperature-related death. The excesses of temperature have the ability to kill. Most of the additional deaths throughout periods of thermal extreme will be in people with prior disease, particularly cardiac and breathing sickness. The very old, the very young and the weak will be the most vulnerable. Without acclimatization, the influences would be increased.

Fluctuations in temperature and precipitation will have numerous harmful effects on social health. Temperature rises will spread disease vector environments. Wherever healthy infrastructure is insufficient, droughts and flooding will affect the occurrence of water-borne diseases. Floods and droughts can cause main social and environmental influences on and disturbances to the economies of African countries.

The results of this paper have been in the same frame of the outputs listed in the IPCC special reports of extreme climates in which the number of warm days TX90p and warm nights TN90p, has been generally increased, and for cold days TX10p and cold nights TN10p, it has been overall decreased.

The impacts of heat waves on the people have been examined by many researchers who have recognized clear relations among extraordinary temperatures and morbidity and mortality, specifically in respirational and cardiac diseases (Bobb et al., 2014; D´ıaz et al., 2015; Gasparrini et al., 2015; Gronlund et al., 2014; Hajat and Kosatky, 2010; Tob´ıas and D´ıaz, 2014; Ye et al., 2012). In the last years, a significant intensification in the number of heat waves has been detected on a global scale (Coumou and Rahmstorf, 2012; Coumou and Robinson, 2013).

Also, as reviewed by Roy´e (2017), the results of high minimum temperature values can be observed through thermal stress perseveres and intensified by the fact that the human body would be banned from nighttime rest, which can lead to changes and deficiencies of sleep due to the necessary procedures of thermoregulation (Buguet, 2007; Joshi et al., 2016). Numerous studies indicated that 19 ◦C was found to be the favored ambient room temperature, and shift from this temperature was convoyed by individual discomfort (Joshi et al., 2016). Fujii et al. (2015) declared that high air temperatures in summertime enlarged exhaustion. In Cameroon it was found that the excess temperature was associated with headaches, weakness, and harmful effects on school performance in the hot interior environments (Dapi et al., 2010).

Figure (9), explains the daily death due to cold and warm spell.

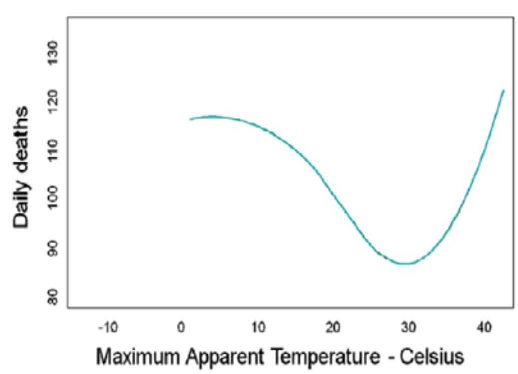

Figure 9: Daily death corresponding to cold and warm extreme temperatures.

4. SUMMARY AND CONCLUSION:

These results of this study gave a warning about the possible impacts of climate change on many vital sectors such as health, agriculture and energy. There have been many direct and indirect impacts of climate change on health for example mortality and morbidity which are caused by extreme events such as droughts and thermal stress (Curtis et al., 2017), as hot waves and cold spell (Roy´e, 2017; and Huynen, 2001). Temperature and air pollution directly have been linked to Cardio-respiratory problems.

A set of many temperature indices computed by CMIP5 multi model ensemble mean was chosen for Libya. It is essential to note that there have been limited available results on observed temperature fluctuations and extremes, and the current work has been the head study of this category which presented a reliable investigation in this region. The sturdiest signs are the significant rises in the occurrence of Warm Days (TX90p) and Warm Nights (TN90p) and significant declines in the frequency of Cool Days (TX10p) and Cool Nights (TN10p), and these have been in contract with the findings of many results over Africa in different regions with similar findings, such as Gamal (2017) who studied the extreme temperature indices over Sinai Peninsula, and Aguilar et al. (2009) in the Central Africa region, and also Chaney et al., 2014 who conducted a study over sub-Saharan Africa. The precipitation indices showed a much less steady pattern of variation through the regions related to the temperature indices. The statistically significant positive trend for warm temperature indices and negative trend for cold temperature indices have been found. The number and duration of heat wave would be increased especially over the coastal region comparing to the inland stations. The outcomes found in this paper have been vital for understanding the extreme climate indices and forthcoming development in the zones of public health, energy and food security in Libya

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