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The Extreme Climate Indices for Benghazi-Libya from Canadian Regional-Climate Model

Dalal M. El-Beshary [1*], S, M. Robaa[1], Gamil G. Abd El-Motey[2], Zeinab Salah[3], and M. M. Abdel Wahab[1]

[1]*Department of Astronomy & Meteorology and Space Science, Faculty of Science, Cairo University, Egypt.*
[2]*Natural Resources Department, Institute of African Research and Studies, Cairo University, Egypt.*
[3]*Egyptian Meteorological Authority, Egypt.*

* Corresponding author: dalal_elbeshary@yahoo.com[1]; zeinabsalah@gmail.com[3]
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Abstract

Extreme weather events present serious threats to existing human life and resource systems. Events such as flooding, extreme heat or cold, heavy or high winds have the ability to destroy, disrupt, and disable vital links. In this article, some patterns of these indices were presented. Representative concentration pathway (RCP4.5) running by the Canadian Regional Climate Model (CanRCM4) during 2011-2041 was used to study the future trend of climate indices over Benghazi in Libya. Totally different extreme climate indices were analyzed like the number of heat and cold waves, summer days and tropical nights. It is clear that the numbers of summer days (SU25) and tropical nights (TR20) have a positive sign, which implies that in each year there is a rise by one day and night. In addition, there is a major decrease within the trend of cold days and nights. For precipitation extreme indices, there are negative trends within the annual range of days: with the precipitation amount ≥ 1mm (-0.73), the annual range of days ≥ 10mm (-0.02), and the annual range of days ≥ 20mm (-0.022). Whereas for the annual total of daily precipitation > 95th percentile (0.041) there is a positive trend, and therefore the trend of the precipitation indices is insignificant as temperature indices, which may be induced to the uncertainty within the physics and parameterization of the precipitation within the regional model. Projection of future climate extreme indices is an important step for stakeholders to put adaptation plans to reduce the vulnerability risks upon society.

Keywords: Statistical downscaling; Extreme events; Libya; Canadian Regional Climate model

1. Introduction

Climate change and extreme weather phenomena are thought of as the most serious environmental challenge that threatens developed and developing countries. A rise within the extremes events such as uncommon heat waves, floods, and droughts, has been observed in recent decades (McMichael, *et al.*, 2003). Study of the intense weather events and their causes is extremely necessary to enhance our weather forecast and to avoid their damaging impacts (Karahacane, *et al.*, 2018, Chisanga *et al.*, 2017, and Gamal, 2017). Libya is considered one of the driest countries within the world, with significant changes recorded in temperature and precipitation throughout the last few decades, which had serious impacts on the environment, human welfare, and socio-economic systems. Climate indices, which defined as a calculated value that can be used to describe the state and the changes in the climate system (IPCC, 2012), allow a statistical study of variations of the dependent climatological aspects, such as analysis and comparisons of times series, means, extremes and trends.

The aim of this research is to review the future trend of extreme climate indices over Benghazi, since Libya experienced some of the intense flash floods like in Benghazi in 1984, Tuber valley in 2011, Tripoli in 2013 and 2014.

2. Data and Methodology

2.1 Study area and Data

Benghazi locates in the northeast of Libya on the Mediterranean coast, between longitudes of 20° and 25° E and latitudes of 31.30° and 32.20° N as shown in Figure 1.

According to Koppen classification, the climate of most of Libya is classed as BSh (Semi-arid) and CSa (Mediterranean) among the coastal regions including Benghazi, which influenced by Mediterranean depressions throughout winter season, and because of its geographical location, most of the precipitation falls as showers. The rainy season over Benghazi starts from September to May, with ~99% of the total annual precipitation, which estimated by approximately 270 mm/year.

To check the impact of the climate change on the flash floods over Benghazi, it has been used the outputs of CORDEX experiments simulated using the Canadian regional climate model (CanRCM4), developed in by Canadian Centre for Climate Modeling (Scinocca, *et al.*, 2016).

The daily precipitation and maximum and minimum air temperature data simulated by CanRCM4 over Africa was used with grid resolution of 0.22 degrees (~25 km) during the period of 2011-2041, (available on: http://climatemodelling.canada.ca/climatemodeldata/canrcm/CanRCM4/index_cordex.shtml). These simulations have been based on the RCP4.5 and RCP8.5 IPCC scenarios. In RCP4.5 the total radiative forcing will be stabilized shortly after 2100 (Thomson *et al.*, 2011), whereas in RCP8.5 scenario the greenhouse gas emissions will increase over time, leading to high greenhouse gas concentration levels (Riahi *et al.*, 2007). Subsequently we have a tendency to use the Climate Data Operators (CDO, available on https://code.mpimet.mpg.de/projects/cdo) to make mathematical interpolation to get a high resolution of 12.5 km and extract the data over Benina station in Benghazi.

Figure 1. Map of Benghazi- Libya

2.2 ClimPACT2 and climate indices

The calculations of the climate indices had been carried out using the R software package ClimPACT2 developed by Alexander and Herold (2016). ClimPACT2 can calculate many climate extreme indices from data stored in text and NetCDF files.

The climate indices related to temperature describe cold and warm extremes; such as the number of summer days (SU25), when the maximum temperature (TX) exceeds 25o C, and tropical nights (TR20) which counts the number of nights when minimum temperature (TN > 20°C). Adding to the temperature percentile-based indices included the number of hot days falling above the 90th and 95th percentile (hot days or TX90), and (very warm days or TX95), respectively, also the warm nights (TN90) and cold nights (TN10). While the precipitation indices describe wet extremes; such the amount of rainfall falling above the 95th (R95pTOT) and 99th (R99pTOT) percentiles, which referred as very wet days, and extremely wet days, respectively.

3. Results and Discussion

3.1 Temperature Extreme Indices

The values of the 95th percentile of maximum temperature (TX95) over Benina station are shown in Figure 2, throughout the period of 2011- 2041, with a linear trend of 0.003 and (p-value) statistical significance of 0.173, the significance of the trend (< 0.05 indicates significance at the 5% level). This figure represents that the annual number of days when the maximum air temperature was less than 0°C is decreasing over Benghazi.

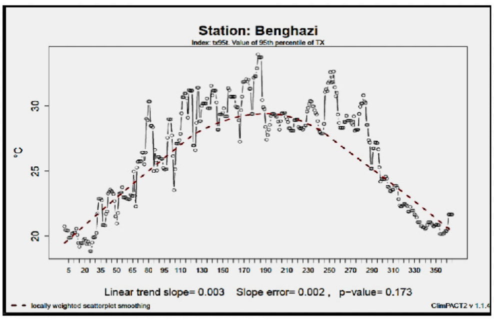

Figure 2 Values of 95th percentile of maximum temperature (TX) over Benina station during the period of 2011- 2041. Plots for the daily threshold values defined periods chosen for TX.

It is possible to identify the heterogeneous behavior of the indices presenting positive and negative trends, indicating a possible influence of local factors. These results are in agreement with those of (Karl and Knight, 1998). These results proof that the annual number of days when the minimum air temperature was above 20°C is increasing and therefore the temporal distribution as shown in Figure3, evidencing the same behavior of this index within the studied area.

The early results of data show that the temperature extreme indices have significant trend than precipitation. It is clear that the linear trend slope of annual SU25 was 1.025, with a slope error of 0.0231, and Tropical nights for Annual count when TN > 20ºC, tropical nights (TR20) has positive significant that mean that each year there is a rise by one day and night. In addition, there is a significant decrease within the trend of cold days and nights. Table 1 shows that the trend of an annual number of days when TX ≥ 30 °C over Benina station was 0.064, and the trend of the annual number of days once TX > 25°C was 1.025, the trend of the annual number of days once TN > 20°C was 0.719. The trend of the warmest daily TX was 0.039, whereas the trend of coldest daily TN was 0.019. Heat wave magnitude (mean temperature of all heat wave events) was 0.035. Annual number of days TM > 5°C, the daily average temperature TM above 5°C the trend was 0.002; slope error p- value was 0.855.

Warm and cold extremes temperature trends for extreme seasonal and annual minimum and maximum temperature at the station for the period (2011-2040), providing a valuable contribution to better understanding of regional scale change compared to the literature that has focused on large-scale variability. The findings generally support previous trends known (Goubanova and Li, 2007), with extremes in cold conditions increasing more rapidly than warm extremes, with a pattern of warming at Benghazi. Significant increases within the coldest extreme (TN) temperature are found in autumn and spring (94% of the station), in winter (88%) and in summer (69%). a mix of increasing and decreasing trends within the warmest day (TX) is found, with significant changes additional evident in autumn and spring than in winter and summer.

3.2 Extreme Precipitation Indices

This study shows that there is a decreasing trend within the annual rain, as shown in Figures 4, and 5. The precipitation extreme indices, (in Table 2), show a negative trends for the annual total of daily precipitation ≥ 1 mm (-0.73), and the annual number of days ≥ 10 mm (-0.02). Also, there is a negative trend for the annual number of days ≥ 20mm (-0.022). However there is a positive trends for the annual sum of daily precipitation > 95th percentile (0.041), for the annual number of consecutive dry days of precipitation < 1.0 mm (0.933), and for the trend for Maximum 1–day precipitation total (0.006). It was found that the trend of precipitation indices is insignificant as temperature indices. Perhaps this data is helpful for stakeholders in adaptation plans to reduce climate risks.

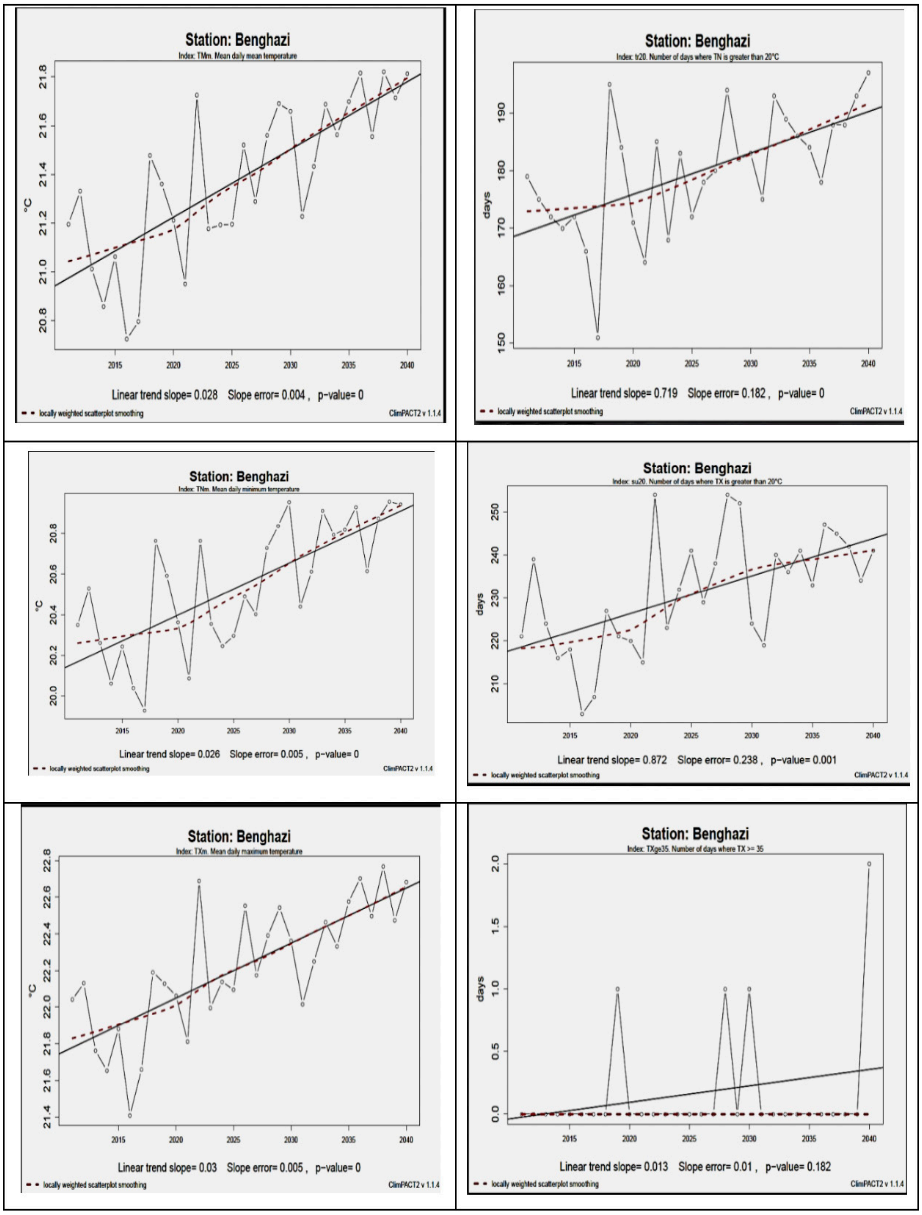

Figure 4. Annual sum of daily precipitation for periods (2011-2040) Benina Benghazi – Libya. Weighted linear regressions (dashed red line) give an indication of longer-term variations, the linear trend line (solid black line), And Statistical Significance (p-value), the significance of the trend (< 0.05 indicates significance at the 5% level).

Table 1. Trend analysis of annual number or day's temperature for Benina station's Benghazi-Libya

Annual number of days	Linear trend slope	Slope error	p-value
TX >25°C	1.025	0.231	0
TN >20°C	0.719	0.182	0
TM>5°C	0.002	0.01	0.855
Warmest daily TX	0.039	0.035	0.272
Coldest daily TN	0.019	0.009	0.056
Warmest daily TN	0.045	0.013	0.002
Coldest daily TX	0.021	0.009	0.029
Mean between TX and TN	0.004	0.003	0.197
TX 95t.value of 95th percentile of TX	0.003	0.002	0.173
Percentage of days of days TX > 50th	0.901	0.174	0
Percentage of days TX < 10th	-0.527	0.147	0.001
Percentage of days TX > 90th	0.23	0.078	0.006
Percentage of days TN < 10th	-0.574	0.131	0
Percentage of days TN > 90th	0.596	0.111	0
Annual number of days TM >= 5 °C	0.006	0.004	0.152
Annual number of days TM >= 10 °C	0.006	0.004	0.152
Annual number of days TX >= 30 °C	0.064	0.078	0.423
Annual number of days TX >= 35 °C	0.013	0.01	0.182
Number of days TX is greater than 20°C	0.872	0.238	0.001
Number of days TN is greater than 20°C	0.719	0.182	0
Mean daily mean temperature	0.028	0.004	0
Mean daily minimum temperature	0.026	0.005	0
Mean daily maximum temperature	0.03	0.005	0
Number of days where TX >= 35	0.013	0.01	0.182

Table 2. Trend analysis of annual number or day's Precipitation for Benina station's Benghazi-Libya

Annual number of days	Linear trend slope	Slope error	p-value
Max. annual number of consecutive dry days (precipitation < 1.0 mm)	0.933	0.662	0.17
Max. annual number of consecutive wet days(precipitation >= 1.0 mm)	−0.024	0.04	0.549
Annual number of days precipitation >= 10 mm	−0.02	0.05	0.69
Annual number of days precipitation >= 20 mm	−0.022	0.015	0.161
Maximum 1−day precipitation total	0.006	0.437	0.989
Annual sum of daily prec. >= 1.0 mm	-0.731	1.258	0.566
Annual sum of daily prec. > 95th percentile	0.041	0.963	0.966
Annual sum of daily prec. > 99th percentile	−0.548	0.659	0.413
r95ptot. 100*r95p / PRCPTOT	0.088	0.27	0.747
r99ptot. 100*r99p / PRCPTOT	−0.182	0.195	0.359
Annual number of days prec. >= 30	−0.003	0.005	0.57

4. Conclusions

This study presented analyses of the trends in eleven annual extreme indices of air temperature and precipitation for Benghazi city in Libya. The analyses have been done throughout the period of 2011-2041, that characterizes a long-term period and with high-quality data set. An increase was noticed within the annual number of days when the TX > 25°C, and in the annual number of days when the TN >20°C.

A predominant increase was identified in the monthly higher and lower values of daily TX, also the warm spells periods increased while the cold spell period decreased. It was clear that a number of summer days (SU25) and tropical nights (TR20) have positive significant trend. In addition, there was a major decrease within the trend of cold days and nights. Precipitation in Benghazi vary greatly, since the precipitation trends in Benghazi increased. The annual sum of daily precipitation > 95th percentile (0.041), and the annual number of consecutive dry days (precipitation < 1.0 mm (0.933) have a positive trend. The data showed that the temperature extreme indices had a vital trend than precipitation whose trend was insignificant over some years; however, there were a few years had significant trends.

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