modelling future temperature change in libya (2020-2099) and it's link to the sustainable development planning

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ABSTRACT

In the 21st century, climate change is considered one of the greatest environmental threats to the world, and it has greater negative impacts on human society and the natural environment. All the IPCC's reports concluded that we should prepare scenarios and strategies for under the conditions of forthcoming global change.

This study presents the projections of future changes under HadCM3 A2a and HadCM3 B2a SRES scenarios using the statistical downscaling model (SDSM) in the period (2020-2099) and their link to the planning of sustainable development in Libya.

Results of downscaling show that the SDSM model can be well acceptable regard its performance. The result of the SDSM model showed great reliability of SDSM in ascertaining changes for the periods; (2020-2039), (2040-2059), (2060-2079) and (2080-2099), relative to 1961–1990. Trend analysis in Libya showed an increase in average annual and monthly temperature, compared to the baseline period for both HadCM3A2a and HadCM3B2a scenarios in both the dry and wet seasons. Thus, there is likely to be a significant warming in local surface temperature, which is enough for a significant change on the energy balance and is likely to affect water availability.

The SDSM is well to help decision-makers understand the expectations of the change in extreme temperatures in the future and its environmental and economic impacts and social in Libya.

Keywords: Statistical downscaling model, SDSM, Intergovernmental Panel on Climate Change IPCC, General circulation model, GCM, HadCM3 Hadley Climate Model version, Temperature, Libya.

نمذجة التغير المستقبلي في درجات الحرارة في ليبيا (2020-2099) وارتباطه بالتخطيط للتنمية المستدامة

الملخص

التغير المناخي أحد أكبر التهديدات البيئية في العالم لما له من اثار سلبية مباشرة على كل الأوساط الطبيعية والبشرية، وخلصت كل تقارير المنظمة الحكومية الدولية المعنية بتغير المناخ بانه يجب علينا اعداد سيناريوهات واستراتيجيات، للتنبؤ بذلك.

ونموذج وسيناريوات(SDSM) تهدف الدراسة لبناء اسقاطات لدرجة الحرارة في ليبيا للفترة (2020-2099) باستخدام تقنية واظهرت النتائج دقة كبيرة لأداء هذا النموذج يمكن ان تساعد صانعي القرار بالبلاد HadCM3 A2aوHadCM3 B2a SRES لأخذ ذلك بالاعتبار في كل خطط التنمية المستدامة. فلقد أظهرت النتائج المتحصل علها من خلال السبع محطات المستخدمة بهذه الدراسة اتجاه واضح في ارتفاع درجات الحرارة بكل فترات النموذج مقارنة بفترة الأساس في كل من المواسم الجافة والرطبة وهذا سوف يكون له اثار كبيرة على امدادات الطاقة والمياه وبالتالي الإنتاج وامدادات الغداء فكل

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هذه الاثار يجب ان تؤخذ بالاعتبار عند الإعداد لخطط التنمية ويمكن من خلاها التخفيف من كل هذه الآثار البيئية والاقتصادية والاجتماعية للتغيرات المناخية مستقبلا في ليبيا.
الكلمات المفتاحية: نموذج التصغير الإحصائي، المنظمة الحكومية الدولية المعنية بتغير المناخ، نموذج الدوران العالمي، نموذج هادلي للمناخ، درجة الحرارة، ليبيا

INTRODUCTION

Sustainable development seeks to meet the needs of people who live today without compromising the needs of future generations. Climate change is considered the most serious environmental challenge threatening all countries of the world, within the seventeen sustainable development goals of the United Nations Goal 13 related to climate change, which will have an impact on the achievement of the sustainable development goals because climate change and sustainable development are closely linked and climate change can undermine sustainable development.

In order to obtain information about the behaviour of our planet after 25, 50 or 100 years, scientists had to build climate models based on symbolic simulations of the behaviour of the atmosphere through computer programs, due to the impossibility of conducting experiments in real conditions. To achieve this, they divided the atmosphere into "cells" of different size according to the accuracy of the model (IPCC, 2007). The conditions prevailing in each cell are determined on the basis of the initial state of the model, and this initial state is often the current situation, or the situation that prevailed in 1990, a reference year for international agreements. (IPCC, 2013), modelling future temperatures is critical to enable us to develop adaptation plans, mitigate its impact, and create favourable conditions for development. Sustainable in the long term.

In this study, a number of global climate models were used with scenarios approved by the Intergovernmental Panel on Climate Change, which are short-term and long-term scenarios to determine the future of the temperature extremes in Libya to help decision-makers understand the expectations of the change in extreme temperatures in the future and its environmental and economic impacts and social.

1. LITERATURE REVIEW

There is much debate in the scientific literature and concern in the wider community about climate change, and it indicates that the magnitude of warming in the 21st century is likely to be the largest in any century during this period. Several studies indicate, for example, (Jones et al. 2003; Arnell, NW 2004; IPCC. 2001; IPCC; 2007, IPCC; 2013).

Indicated that the average annual Earth surface temperature had increased by 0.3-0.6 ° C since the late nineteenth century, and they all pointed to the fact that there is a general upward trend (warming) in global average surface temperature and is expected to increase. Such changes in climate will have a major impact on the ecological, social and economic system.

Obviously, climate change variables developed by IPCC are the most useful data to comprehend the climatic condition whether it is at global level or national level (Mearns et al., 2001).

Projection of future climate trend will be highly essential for the environmental planning and management. Changes in climate conditions may promote the events of draught or flood extremes therefore, the investigation on the temperature impacts on the present and future is highly demanded (IPCC, 2013).

On the other hand, GCMs are the currently most reliable tools to assess climate change at coarse scale but GCMs output do not meet the needed resolution to assess the climate change at regional or local scales. The grid-boxes used by GCMs are too coarse (Wilby et al., 2004). Then, GCMs cannot present the local weather and micro-climate processes.

In order to better assess projected climate change estimates at the micro level (regional and local), climate variables and climate change scenarios must be developed at a regional or even site-specific scale
to provide these values, projections of climate variables must be "miniaturized" from the GCM results, using either dynamic or statistical methods (Wilby, & Dawson (2007).

2. Definition of the problem

Climate change is a consequence of changing in climate on environment over the worldwide. The increase in developmental activities and Greenhouse Gases (GHGS) put a strain on environment, resulting in increased use of fuel resources; the subject of global warming has initiated this investigation concerning temporal changes of extreme temperatures in Europe and North of Africa.

Carbon dioxide has increased by 31 percent, methane by 151 percent and nitrous oxide by 17 percent. The continuing of this greenhouse gas emissions phenomena at this rate, will lead to further warming and unexpected changes in the global climate system in the future (Solomon et al., 2007).

With the emergence of what was known as the Industrial Revolution, human activity led to a rise in the global temperature of one degree Celsius during the period (2006-2017) ±. 0.12 ° C compared to the
period (1850-1900) and if the current rate of warming continues, the global warming caused by human activity will reach 1.5 ° C in 2040. Under the 2015 Paris Agreement, countries agreed to reduce greenhouse gas emissions and to continue efforts to reduce of global warming at 1.5 ° C above pre-industrial levels (IPCC; 2013).

3. The importance of the study

Although this global warming shows that the temperature of the Earth as a whole is changing, a close examination of certain regions and countries will reveal important details. Since the 1970s, most of the interior regions have warmed more rapidly than the global average, meaning that warming in many regions has already exceeded 1.5 ° C above pre-industrial levels, these regions contain more than a fifth of the world's population, and this will lead to Increasing extremely hot days in all land areas. It will also lead to increased precipitation in some areas, which may increase flood risks.

In addition, it is expected, that some regions, especially around the Mediterranean, will shift in the distribution of plant and animal species, decrease in crop yields, increase the frequency of forest fires and work to end or reduce sources of warming will help in achieving some sustainable development goals and planning to confront climate change and to maximize synergies and reduce conflicts with sustainable development.

This study utilized the Statistical Downscaling Model (SDSM), developed by (Wilby & Dawson (2007). Libya is one of the driest countries in the world with significant changes recorded in temperature.

4. Objectives of the Study

In this study the general circulation model (GCM) output of HadCM3 to predict the future climate variables and statistical downscaling model (SDSM) to change the coarse resolution of climate variables to the finer scale are used to estimate the future daily temperature for seven climatic stations in Libya.

Specific objectives of this study are:

To compare the HadCM3 output of air temperature with observed trends from the weather stations records.

To determine the future trends of daily temperature up to 2099 in Libya.

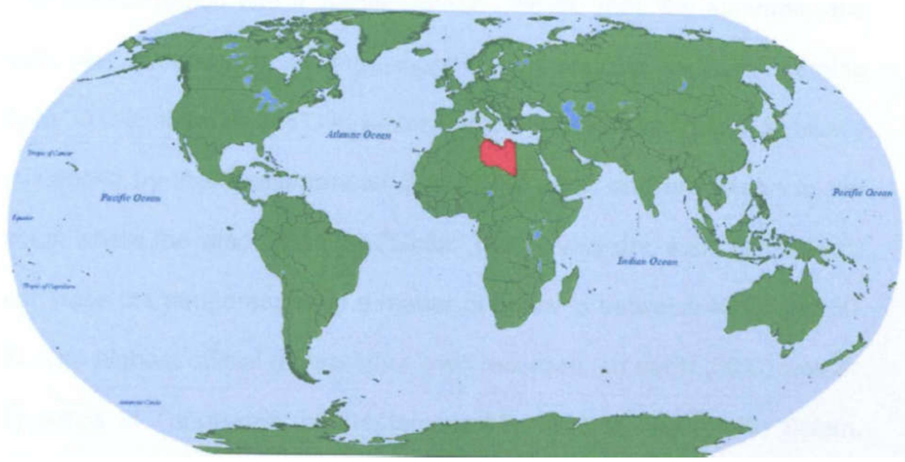
3. Study area

Libya is located in North Africa along the southern Mediterranean coast Figure (1). It extends between 20° and 34° N and 10° to 25° E; area of Libya is 1.674.577 km2 within which 95% is extremely arid deserts. The elevation ranges from –59 m to 2,314 m, with an average altitude of 423 m.

The climate is generally described as arid to semi-arid, with hot and dry summers and moderate winters with erratic rainfall.

The varies of mean annual temperature gives the fact that the north of Libya corresponding to the Mediterranean Sea compared to the south, which is a proportion of the extremely arid Sahara of Africa. Libyan Survey Authority, (1979).and (General Information Authority of Libya, (2020).

Figure (1) Location of Libya



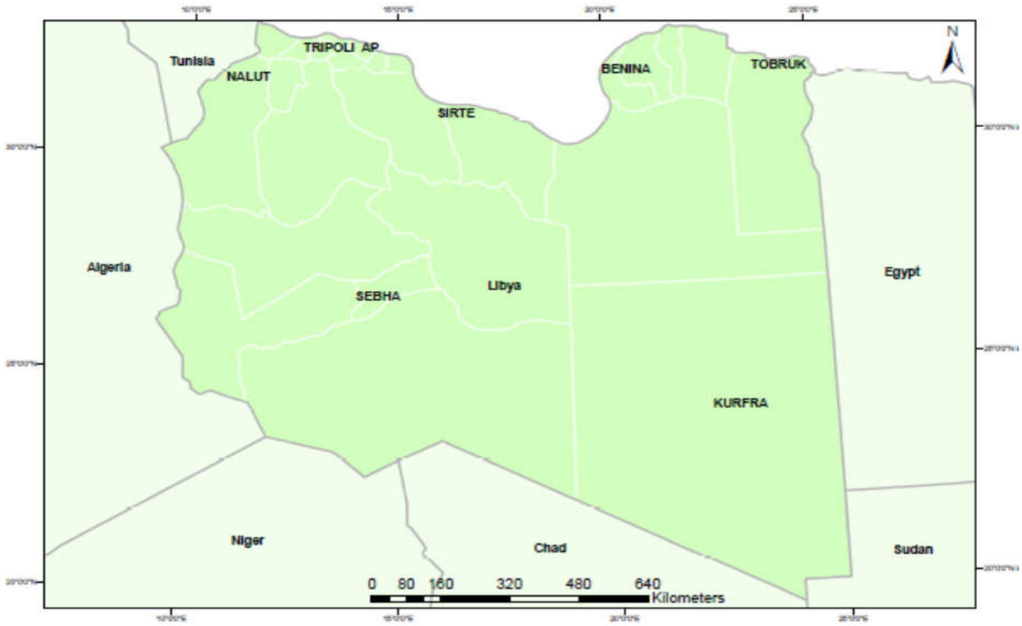
Source: Abdussalam Ibrahim, 2010, page 12

1. DATA & METHODOLOGY

6.1 Data

Daily temperature of seven selected climatic stations in Libya Figure (2) for thirty years (1961-1990) were used to parameterise the downscaling model for the study area. The NCEP reanalysis predictor sets used for the calibration process to provide gridded reanalysis data sets used in the calibration process of SDSM, the National Centre for Environmental Prediction (NCEP) products were interpolated to the CGCM2 grid over the entire African continent are. Both the GCM variables and the NCEP data sets were made available for the grid-boxes illustrated in Figure (3).

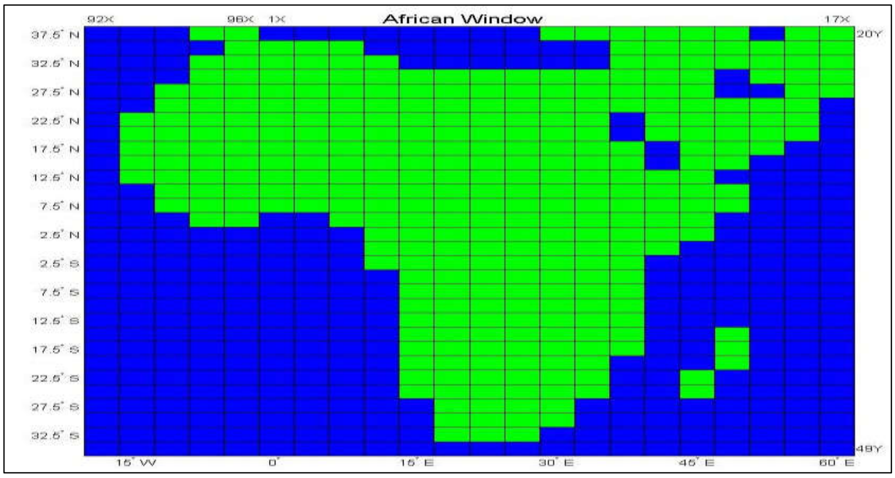
Figure 2. Location of selected climatic stations in Libya for statistical downscaling



Source: Researcher using Arc GIS 10.7.1

The projected GCM output for both the CGCM2 and HadCM3 were used, these predictor sets are available for four future periods; (2020-2039), (2040-2059), (2060-2079) and (2080-2099). They are in the form of daily data from the SRES A2 and B2 emissions experiment normalized with respect to 1961-1990.

Figure 3. Location of grid cells for statistical downloading

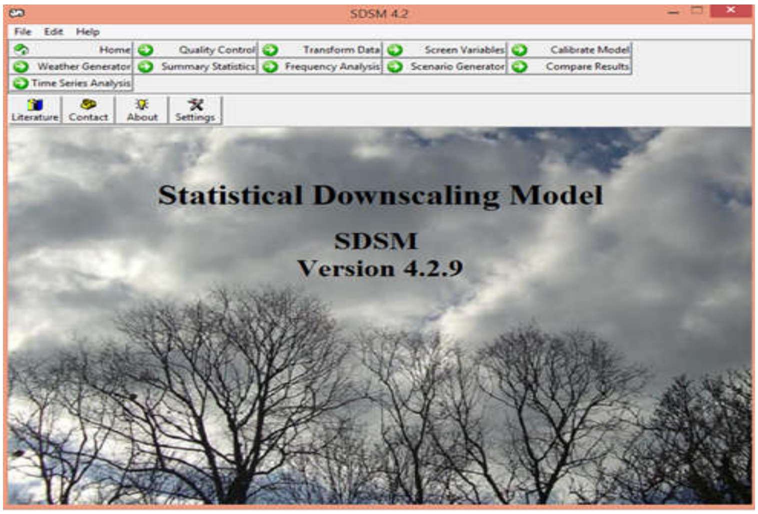


Sourcehttps://sdsm.org.uk/data.html

6.2 Methodology

The methodology used in this study is fully described in the SDSM 'User's Manual', by Wilby Dawson and Barrow (2007). It is a decision support tool used to assess local climate change impacts using a statistical downscaling technique Figure (4). The aim is to assess the suitability of the HadCM3 climate scenario to simulate climate variables in the study area against observed climate data, in order to guide their use in climate change projections. IPCC (2001; 2007) state that coupled models provide credible simulations of the present climate. This approach involves comparing GCM simulations that represent present-day conditions (baseline climate period) to observed climate values in order to check the validity of the GCMs in Libya specifically, for the baseline period (1961 to 1990). The IPCC recommends 1961-1990 as climatological baseline period in impact assessment, the HadCM3 model was employed for both A2 (Medium-High Emissions) and B2 (Medium-Low Emission) Scenarios. HadCM3 is widely applied in many climate change impact studies; see for example Lucio (2004), Sanchez et al. (2004) and Jones et al. (2004).

Figure 4. SDSM Software



Source: https://sdsm.org.uk/software.html

The predictor variables selected for temperature of Libya for each downscaling process conducted in this study are (Surface meridional velocity, Surface wind direction, 850 hPa wind direction, 500 hPa geopotential height, 500 hPa wind direction, 500 hPa divergence, 850 hPa meridional velocity, 850 hPa geopotential height, 850 hPa wind direction, Mean temperature at 2m).

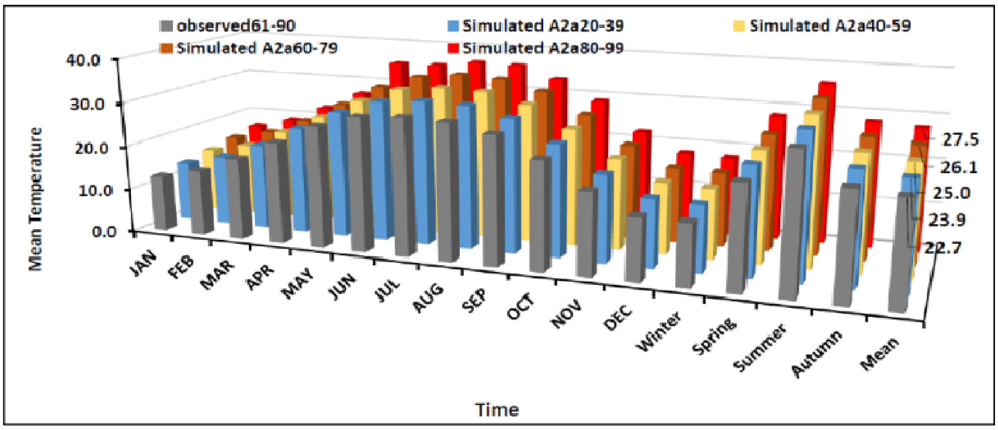
All GCMs provide a version of the future, based on which emission scenario and time frame, in this study, the SRES A2 and B2 emission scenario were used for four future periods; (2020-2039), (2040-2059), (2060-2079) and (2080-2099).

ESULTS

7.1. Downscaling of future changes in temperature for the A2a scenario

The climate scenario for the future period was developed from statistical downscaling using the GCM (HadCM3) predictor variables for the A2a emission scenario, based on the ensemble of 20 models. Analysis was based on periods (2020-2039), (2040-2059), (2060-2079) and (2080-2099). The respective average change from the baseline period were calculated for monthly and seasonally of the temperature.

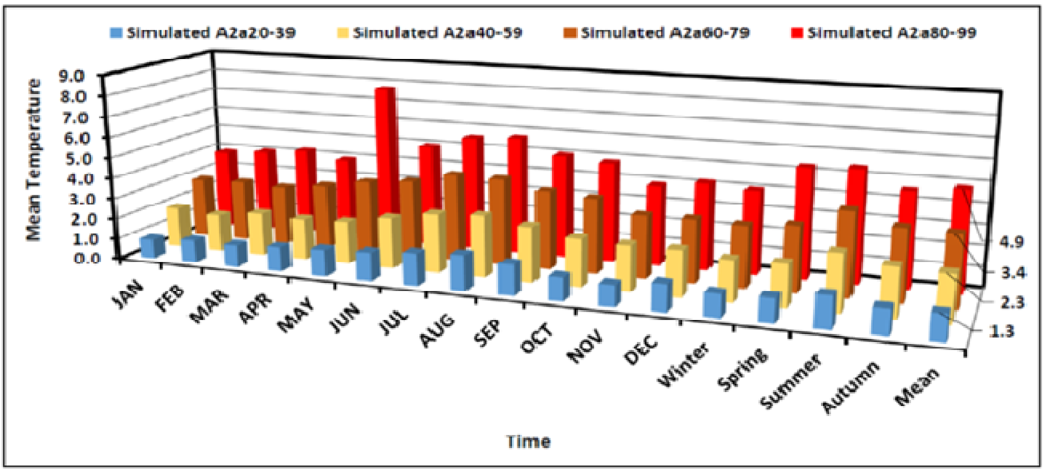
Figure 4. Simulated mean monthly and seasonal temperature for the period (2020-2099) with HadCM3A2a scenario for Libya



Source: Researcher depending on the output of SDSM Software

Figures 4 and 5 shows the observed and modelled result of mean monthly and seasonal temperature of daily surface temperature in Libya. The downscaling of temperature in the future period (2020-2099) for HadCM3A2a scenario shows an increasing trend in all future time horizons. The average annual temperature is predicted to increase by 1.3°C by the period (2020-2039). By the period (2040-2059), the increase is predicted to be 2.3°C under the A2 scenario. By the period (2060-2079) the average annual temperature is predicted to increase by 3.4°C under the A2 scenario and will increase to 4.9°C by the period (2080-2099). under A2a scenario. The downscaling model correctly shows that the highest mean monthly temperature are observed in May, June, July, August and September while the lowest are observed in January, February and December.

Figure 5. Simulated change in monthly and seasonal temperature for the period (2020-2099) with HadCM3A2a scenario for Libya



Source: Researcher depending on the output of SDSM Software

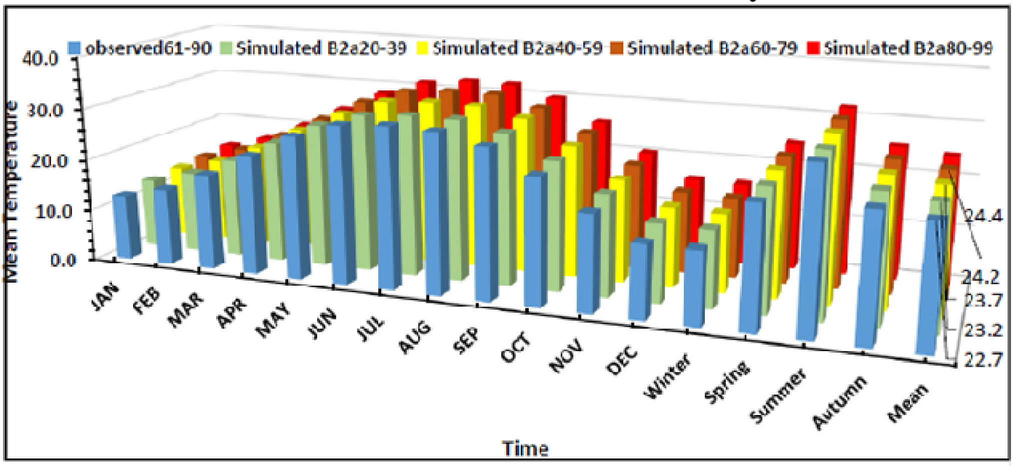
Results were generated by seasonal temperature in the baseline period (1961-1990) and downscaled for A2 scenarios indicates that the highest rise will be in the Summer Season, which predicted to increase respectively for the periods (2020-2039), (2040-2059), (2060-2079) and (2080-2099) by 1.5°C 2.7°C, 4.0°C and 5.4°C.

Also Results were generated by seasonal temperature in the baseline period (1961-1990) and downscaled for A2 scenarios indicates that the lowest rise will be in the Winter Season, which predicted to increase respectively for the periods (2020-2039), (2040-2059), (2060-2079) and (2080-2099) by 1.1°C 2.0°C, 3.0°C and 4.1°C.

7.2. Downscaling of future changes in temperature for the B2a scenario

The downscaling of temperature in the future periods for HadCM3B2a scenario in Libya shows an increasing trend in all future time horizons for the periods (2020-2039), (2040-2059), (2060-2079) and (2080-2099).

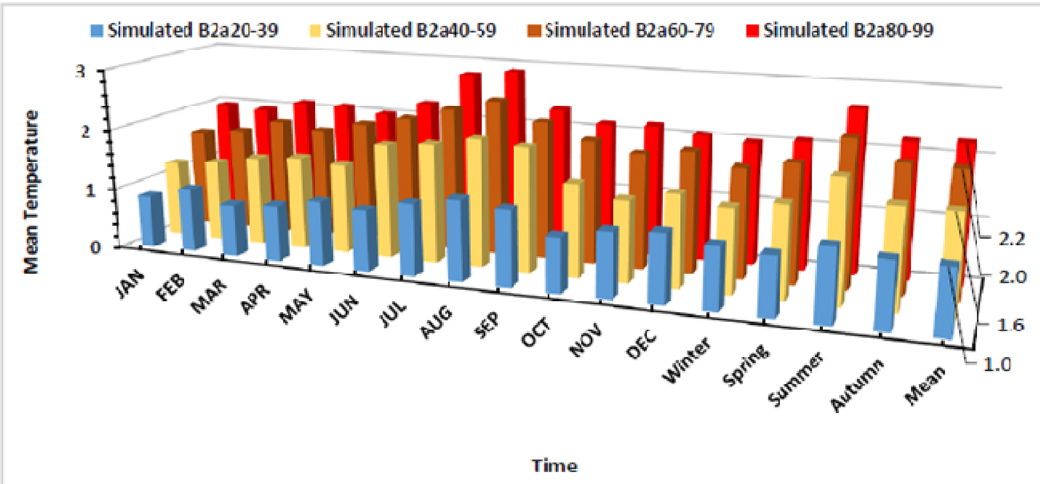
Figure 6. Simulated mean monthly and seasonal temperature for the period (2020-2099) with HadCM3B2a scenario for Libya



Source: Researcher depending on the output of SDSM Software

Figures (5) and (6) indicate that the increase will be respectively 1.0°C 1.6°C, 2.0°C and 2.2°C for the periods (2020-2039), (2040-2059), (2060-2079) and (2080-2099).
It indicates also that the highest rise in mean monthly temperature will be between 2.3°C to 2.9°C in June, July and August.

Figure 7. Simulated change in monthly and seasonal temperature for the period (2020-2099) with HadCM3B2a scenario for Libya



Source: Researcher depending on the output of SDSM Software

Results were generated by seasonal temperature in the baseline period (1961-1990) and downscaled for B2a scenarios indicates that the highest rise will be in the Summer Season, which predicted to increase respectively for the periods (2020-2039), (2040-2059), (2060-2079) and (2080-2099) by 1.2°C 2.0°C, 2.4°C and 2.7°C.
Also Results were generated by seasonal temperature in the baseline period (1961-1990) and downscaled for B2a scenarios indicates that the lowest rise will be in the Winter Season, which predicted to increase respectively for the periods (2020-2039), (2040-2059), (2060-2079) and (2080-2099) by 1.0°C 1.4°C, 1.8°C and 2.0°C.

8. DISCUSSION

Generally, this study attempted to make some predicitions about future climate trends in Libya by statistical downscaling of GCM output. the data suggest that the mean monthly temperature will increase in the future period. The change in temperature from the baseline period is higher in the dry months than the wet months under both A2a and B2a scenarios.

As expected, the HadCM3A2a scenario predicts greater increase than the HadCM3B2a scenario. The HadCM3A2a scenario represents a medium high scenario based on a greater increase in atmospheric CO2 concentration than is used in the HadCM3B2 scenario.

The purpose of this was to use these data within any future sustainable development goals in Libya, because climate change can undermine sustainable development as described in the United Nations Goal 13.

The projected temperature trends for all future time horizons are within the range projected by IPCC climate change scenarios, which indicate future warming across North Africa (Mediterranean coast) with ranges from 2oC (low scenario) to 5oC (high scenario) by 2100.

Overall, the results of this study agree with El Kenawy et al. (2008), who found strong evidence of a significant warming trend in annual temperature in Libya (0.23°C), resulting in an increase in the mean surface temperature.

The IPCC sensitivity analysis result indicates that an increase in (1°C) in temperature reduces the annual average rainfall by 10%. IPCC (2008). Alkolibi (2002) asserted that GCMs suggest a lower likelihood of rainfall over the Mediterranean and North Africa, including Libya. Arnell (2004) found that annual rainfall from the Hadley Centre GCM (HadCM3) decreases around the Middle East and North Africa. Therefore, and because of a decrease in total rainfall, the frequency and severity of droughts might increase, as well as greater reference evapotranspiration (Frederick and Gleick, 1999).

9. CONCLUSIONS

This study attempted to make some predictions about future temperature trends by statistical downscaling of GCM output. The method worked well for temperature, in addition, as indicated in the SDSM manual. Wilby and Dawson, (2007), local temperatures are largely determined by regional forcing.

The future change from the baseline period for all scenarios for the four future time horizons indicates that increase in temperature. The projected temperature trends for all future time horizons are within the range projected by IPCC for North Africa (Mediterranean coast) towards the end of this Century.

Generally, it is possible to conclude that the statistical downscaling method is able to simulate temperature for the purpose of future predictions for Libya, trend analysis in Libya showed an increase in average annual and monthly temperature, compared to the baseline period (1961-1990) for both HadCM3A2a and HadCM3B2a scenarios in both the dry and wet seasons.

However, this increase is higher in dry months than wet months for all future time horizons and for both HadCM3A2a and HadCM3B2a scenarios. Thus, there is likely to be a significant warming in local surface temperature, which is enough for a significant change on the energy balance and is likely to impact water availability, drought frequency and intensity is likely to increase in the near future, continuing the trend already observed from the last years.

Finlay, temperatures trends would also have to be taken into account of any sustainable development plan in Libya because likely future effects on it.

10. RECOMMENDATIONS

1- The use of several general circulation models for climate change studies able to get the better result for future climate change in Libya.

2- Besides, this study can be extended by considering change in other climate variables in addition to the change in temperature.

3- Further studies should consider other several climatic stations data in Libya.

4- Improving natural recourse management efficiency should be a priority of Libyan government. It needs to prepare a national plan for adaptation to climate change.

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