Future Changes in Maximum Temperature Events Using the Statistical Downscaling Model (SDSM) in Zlitan Area–Libya

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ABSTRACT

In the 21st century, climate change is considered to be one of the greatest environmental threats to the world, and the changes in climate extremes are estimated to have greater negative impacts on human society and the natural environment than the changes in mean climate.

All the IPCC's five reports between 1990 and 2013 concluded that we cannot expect stable climate in the future and we should prepare scenarios and strategies for the survival of humankind under the conditions of forthcoming global change.

This study presents the projections of future changes in maximum temperature events under A2 and B2 SRES scenarios using the statistical downscaling model (SDSM) in the Zlitan Area–Libya.

In order to explore the SDSM method, at Zlitan station in Libya has been selected as a study site to test the methodology for maximum temperature. The study included calibration and validate with large-scale atmospheric variables encompassing NCEP reanalysis data, the future estimation due to a climate scenario, which are HadCM3 A2 and HadCM3 B2 . Results of downscaling show that during the calibration and validation stage, the SDSM model can be well acceptable regard its performance in the downscaling of daily maximum temperature.

The result of climate projection reveals that the SDSM model showed great reliability of SDSM in ascertaining changes for the periods 2011–2040, 2041–2070 and 2071–2099, relative to 1961–1990 and it has very good ability to replicate the historical maximum temperature for the observed period. Trend analysis in the study area showed an increase in average annual and monthly maximum temperature, compared to the baseline period 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.

Keywords: Statistical downscaling model, SDSM, Intergovernmental Panel on Climate Change IPCC, General circulation model, GCM, Special Report on the Emission Scenarios, SERS, HadCM3 Hadley Research Center's Hadley Climate Model version, Maximum temperature, Zlitan area, Libya.

INTRODUCTION

All the Inter- governmental Panelon Climate Change (IPCC's five reports) , between 1990 and 2013 concluded that),global(land and ocean) average temperature has shown a 0.85 °C

(0.65–1.06 °C) increase over the period of 1800–2012(IPCC, 2013), and a 0.7470.18 °C increase during the last hundred years(1906– 2005)(IPCC, 2007). However, the changes in extreme temperature events such as heat waves, severe winter and summer storms, hot and cold days, and hot and cold nights(Mastrandrea et al.,2011) can cause more severe impacts on human society and the natural environment.

Consequently , in the last few years there is much discussion in the scientific literature and concern in the wider community about climate change, the subject of global warming has initiated this investigation concerning temporal changes of extreme temperatures in Europe and North of Africa, recent climate analyses for the last 1000 years over the northern hemisphere indicate the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850), it also Indicate that the magnitude of 21st Century warming is likely to have been the largest of any century during this period. Numerous studies (e.g., IPCC. 2001 ; Jones et al. 2003; Sanchez etal.,2004; IPCC. 2007). It is reported in AR5 that between1951 and2010,the number of warm days and nights has increased, and the number of cold days and nights has decreased on a global scale. In addition, the time length and frequency of warm spells, including heat waves, have also increased since the middle of the20th century(IPCC, 2013).

OBJECTIVE 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 maximum daily temperature for Zlitan station in Libya.

Specific objectives of this study are:

- To compare the HadCM3 output of maximum air temperature with observed trends from the weather station records.
- To determine the future trends of maximum daily temperature up to 2099 for Zlitan station in Libya.

STUDY AREA

Zlitan area is located in North West of Libya between 31° 96 –32° 53 Lat and14° 09- 14° 74 Lon, as shown in Figure (1).

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

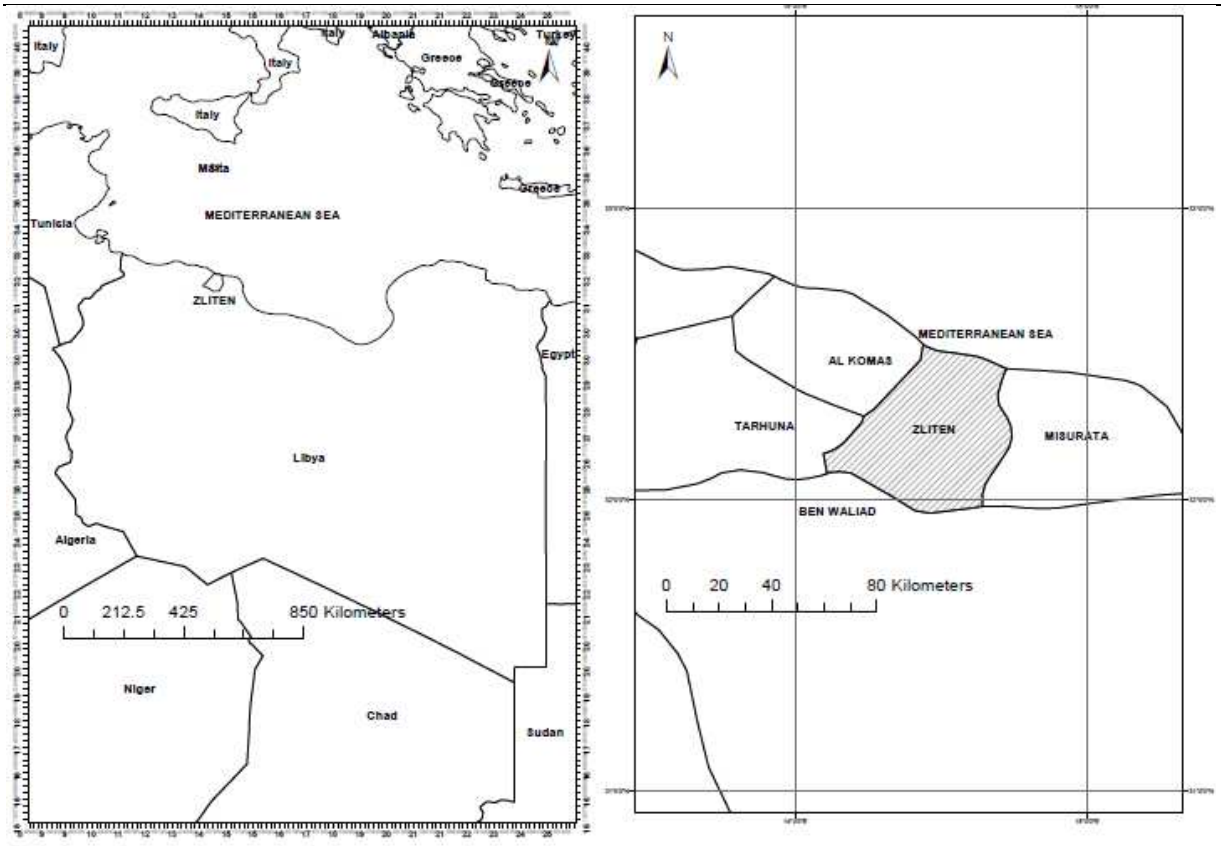

Figure (1) Location Map of Study Area

DATA

Daily maximum temperature of Zlitan station in Libya 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 (2).

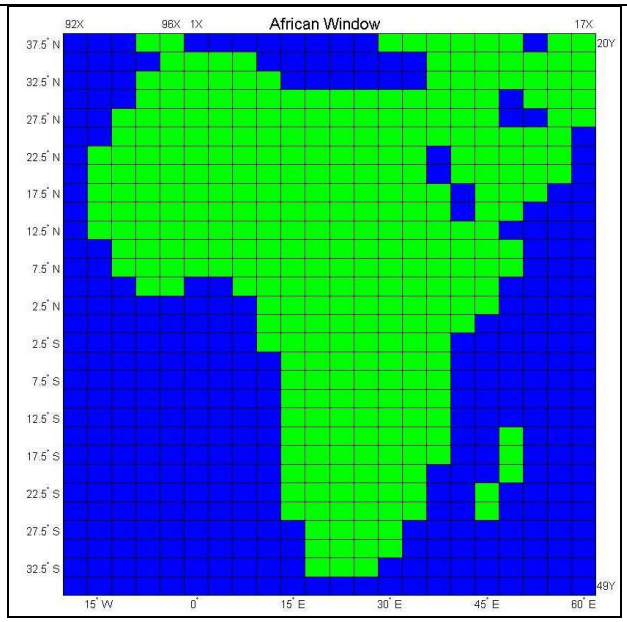

Figure (2) Location of grid cells for statistical downloading

The projected GCM output for both the CGCM2 and HadCM3 were used, These predictor sets are available for three future 30-years periods; the 2020s (2011-2040), the 2050s (2041-2070), and the 2080s (2071-2099).They are in the form of daily data from the SRES A2 and B2 emissions experiment normalized with respect to 1961-1990.

METHODOLOGY

The methodology used in this study is fully described in the SDSM 'Users Manual', by Wilby Dawson and Barrow (2007). 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 and in the Zlitan area 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).

The predictor variables selected for maximum temperature of Zlitan 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 three future tri-decadal periods; the 2020s (2011-2040), the 2050s (2041-2070), and the 2080s (2071-2100).

RESULTS

Downscaling for future changes in maximum temperature

In SDSM 4.2.9, the scenario generator operations are used to produce ensembles of synthetic daily weather series given daily atmospheric predictor variables supplied by a GCM. After the calibration and validation of SDSM model carried out, the daily future climate variables are projected until 2099 using the HadCM3 Global Circulation Model. The projection generates 20 ensembles of daily climate variables, which are equally plausible hence; these ensembles are averaged out in order to consider the characteristics of all those 20 ensembles.
in this study, the SRES A2 and B2 emission scenario were used for three future periods; the 2020s (2011-2040), the 2050s (2041-2070), and the 2080s (2071-2099).
Results were generated by monthly maximum temperature in the baseline period (1961-1990) and downscaled for A2 and B2 scenarios (2011-2040), (2041-2070) and (2071-2099) for Zlitan station are shown in Figures (3) and (4).

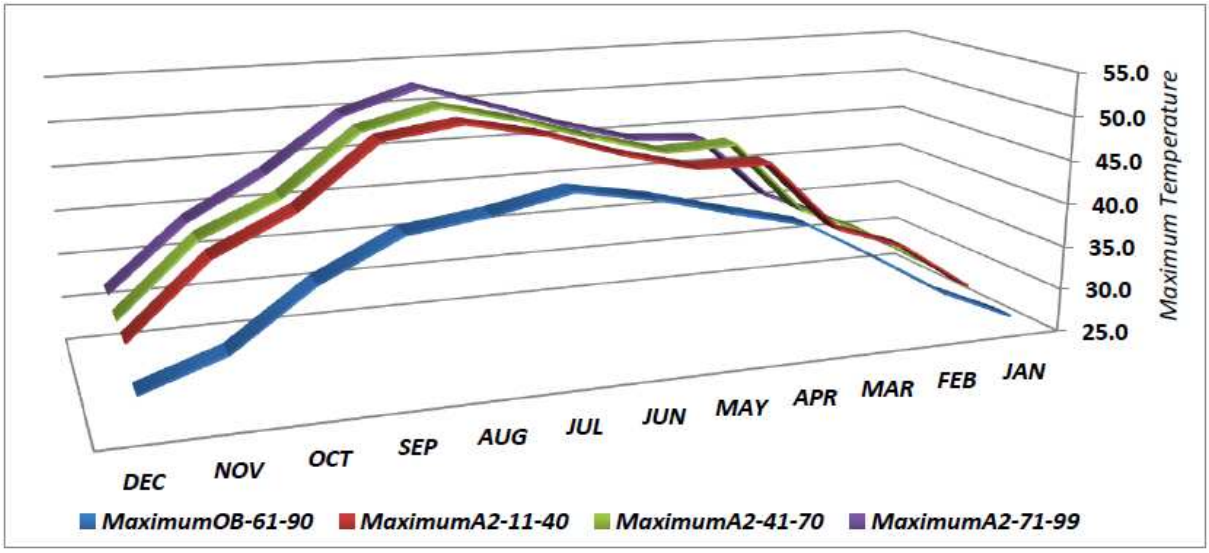

Figure 3 :- Downscaled monthly maximum temperature for the baseline period (1961-1990)with HadCM3A2a scenario for Zlitan station (1961-2099).

The downscaling of maximum temperature in the future period (2011-2099) for HadCM3A2a and HadCM3B2a scenarios shows an increasing trend in all future time horizons. The average annual maximum temperature is predicted to increase by 0.1°C by the 2020s (2011-2040) under both A2 and B2 scenarios. By the 2050s (2041-2070) the increase is predicted to be 0.6°C under the A2 and B2 scenarios. By the 2080s (2071-2099) the average annual maximum temperature is predicted to increase by 0.7°C under the A2 scenario and increase by 0.1°C under B2 scenario.

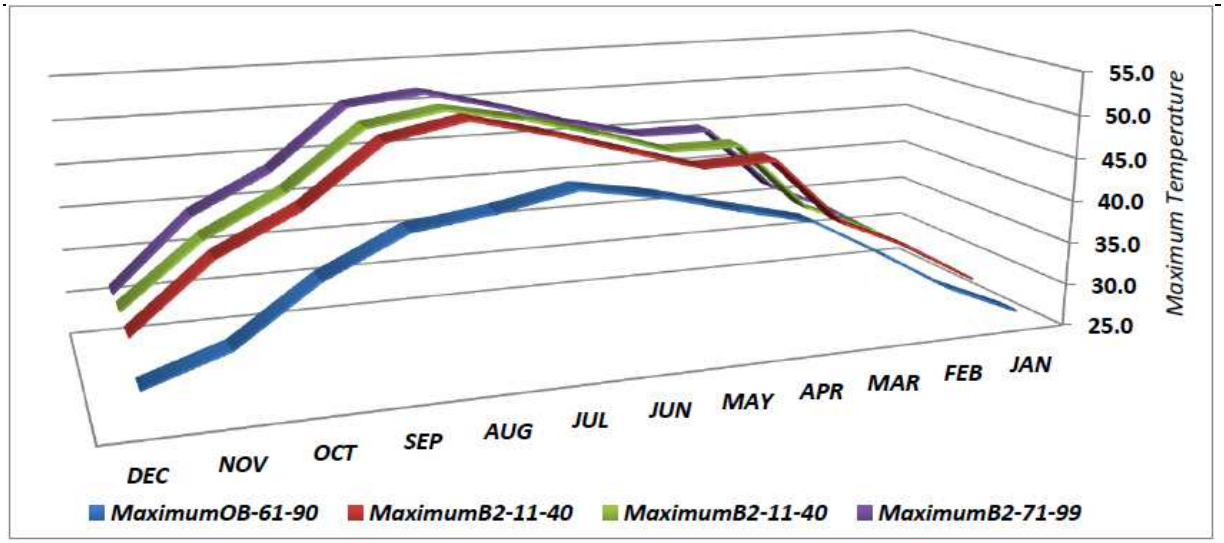

Figure 4 :- Downscaled monthly maximum temperature for the baseline period (1961-1990)with HadCM3B2a scenario for Zlitan station (1961-2099).

Figure (5) shows comparison of the baseline period (1961-1990) and the outputs of the monthly maximum temperature under both A2 and B2 scenarios for the periods 2011-2040, 2041-2070 and 2071-2099.

The graphical also indicates that there will be an increasing trend for both A2 and B2 scenario. Comparatively, A2 which is the high emission Scenario prevail higher change in maximum temperature than B2.

These data predict an increasing maximum temperature for both A2 and B2 scenarios.

Change from the baseline period is high in dry months for all periods and both scenarios, while wet months showed less increase than dry months, and this has important implications for future human activities in the Zlitan region.

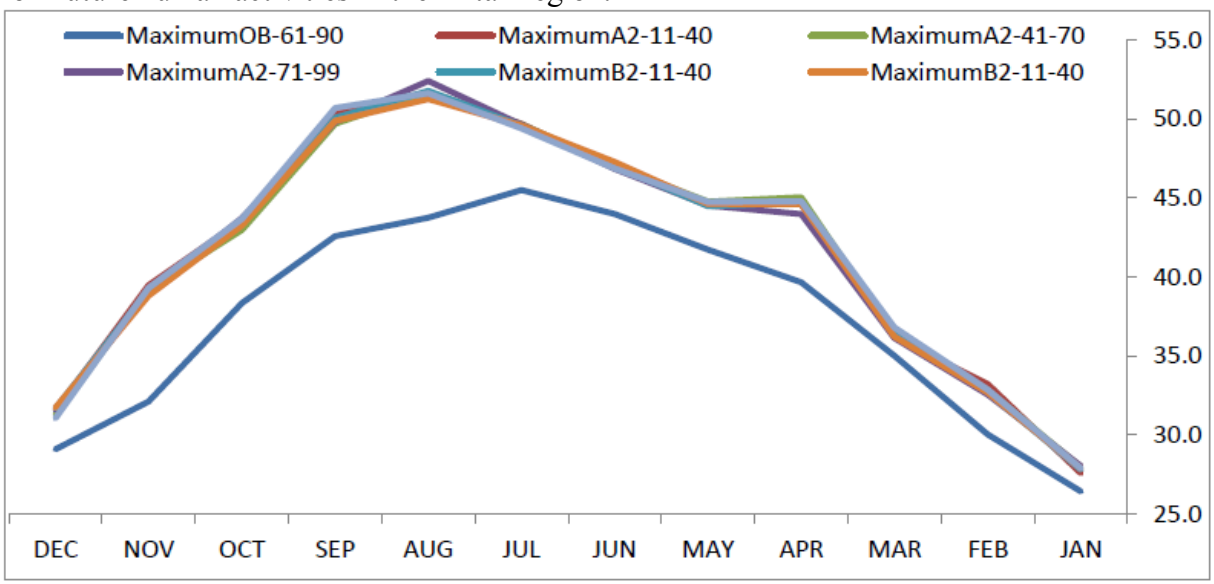

Figure 5 Comparison of maximum temperature for the baseline period (1961-1990)with HadCM3A2a & HadCM3B2a scenario for Zlitan station (1961-2099).

The projected maximum temperature in 2011-2040 indicates that the highest rise in maximum temperature will be between 6°C to 7°C in June, July and August for both the HadCM3A2a and HadCM3B2a scenarios and the lowest rise will be between 1.2°C to 1.5°C in January, February and March, again for both HadCM3A2a and HadCM3B2a scenarios.

CONCLUSIONS

Statistical downscaling method is an alternative tool to downscale global climate model into a fine scale region. In the present study, SDSM, a widely used decision support tool, The followings are the main conclusions of this study.

The results from A2 and B2 were comparable with NCEP, which proves the applicability of SDSM to simulate extreme temperature indices for the future.

The maximum temperature shows an increasing trend in all future time horizons for both A2 and B2 scenarios.

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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