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Long Term Impact of Climate Change on air Temperatures of Greater Zab River Basin, Iraq

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ملخص البحث:

يعد تغير المناخ مشكلة عالمية مشتركة ويؤثر على العديد من قطاعات الحياة على الأرض. ظاهرة الاحتباس الحراري الناجمة عن انبعاثات غازات الاحتباس الحراري تتزايد نتيجة للأنشطة البشرية. ستؤدي درجات حرارة الهواء المرتفعة إلى تغيرات شديدة في المحاصيل الزراعية والموارد المائية والتربة والظروف المناخية واستمرار ذوبان الجليد. تركز الدراسة الحالية على التحري في آثار تغير المناخ على درجات حرارة الهواء فوق حوض نهر الزاب الكبير عند محطة قياس إسكي كلك (20435 كيلومتر مربع) خلال الفترة المرصودة (1979-2005) والفترتين المستقبلية عند منتصف القرن الحادي والعشرين (2047-2073) و نهاية القرن الحادي والعشرين (2074-2100) تحت سيناريوهين الانبعاث المتوسط (RCP4.5) والمرتفع (RCP8.5). تم استخدام نموذج المناخ الإقليمي RCA4 بواسطة برنامج (CORDEX) للحصول على تنبؤات لمتوسط درجات حرارة الهواء ضمن منطقة الشرق الأوسط وشمال إفريقيا (MENA). تم اعتماد متوسط درجة حرارة الهواء المرصودة والمستقبلية اليومية والشهرية في تحليل البيانات. اظهرت النتائج احتمالية حدوث زيادة في درجات حرارة الهواء خلال الفترة المتوقعة مقارنة بالفترة المرصودة. خلال الفترتين المستقبلية, المعدل السنوي لعدد الايام الباردة سيتناقص في حين عدد الايام الحارة سيزداد. أشارت دالة كثافة الاحتمال (PDF) إلى أن تكرار الأحداث التي تزيد عن 12 درجة مئوية خلال الفترتين المستقبلية كانت أكثر حدوثا مقارنة بالفترة المرصودة. سيرتفع المتوسط السنوي لدرجات الحرارة المستقبلية تحت السيناريو RCP4.5 ليصل إلى 1.92 و 2.35 درجة مئوية مقارنة بالفترة المرصودة بينما عند السيناريو RCP8.5 سيكون حوالي 2.84 و 4.64 درجة مئوية خلال فترتين المستقبلية (القريبة والبعيدة) ، على التوالي. إن ارتفاع درجات حرارة الهواء في جميع أنحاء الحوض بسبب تغير المناخ له آثار سلبية على العديد من جوانب الحياة بما في ذلك كمية ونوعية الموارد المائية والقدرة على حماية صحة الإنسان والحفاظ على النظم البيئية.

Abstract:

Climate change is a global common problem and affects many sectors of life on earth. Global warming phenomena induced by emissions of greenhouse gases which increasing as result the human activities. High air temperatures will be caused severe changes in agricultural yields, water resources, soil, climatic conditions and the continued melting of glaciers. The current study focuses on investigate the impacts of climate change on air temperatures over the greater zab river basin at Eski-Kalak gauging station (20435 km^2) during the observed period (1979-2005), mid-21st century (2047-2073) and end-21st century (2074-2100) forecasted periods under both emission scenarios the medium (RCP4.5) and the high (RCP8.5). The regional climate model RCA4 by using Coordinated Regional Climate Downscaling Experiment (CORDEX) program has been employed to acquire the projections of average air temperatures within Middle East North Africa (MENA) region. Daily and monthly of observed and future average air temperature were adopted to analysis data. The results demonstrated increasing in air temperatures will be occur during the predicted period relative to the observed period. At future periods, average annually of number of cold days would decrease whereas, increasing number of hot days. Probability density function (PDF) indicated the frequency of events higher than 12 °C during projection periods were more occurrence compared to the observed period. The average annually of future temperatures under scenario RCP4.5 would raise to reach by 1.92 and 2.35 °C relative to the observed period while, at scenario RCP8.5 will be approximately 2.84 and 4.64 °C during near and distant future periods, respectively. Rising air temperatures over all the basin owing to climate change have adverse impacts on the many aspects of life including the quantity and quality of water resources and the capability to protect human health and preserve ecosystems.

Keywords: greater zab basin, global warming, air temperatures, bias correction, emission scenarios.

1. Introduction

Climate change in these days is a universal challenge and issue of our times. Human impact on the weathering process is unequivocal. The greenhouse gases resulting from anthropogenic emissions lead to the global warming are the large in date, thus social and natural regimes will affected with the climate changes [1]. Latest predictions of Intergovernmental Panel on Climate Change IPCC, according to the 2007 Fourth Assessment Report show that the global surface temperature is possible to increase by about 1.1 to 6.4 °C during the 21st century. Global warming affects on numerous life aspects on Earth, will include negative effect on agricultural sector, weather conditions and water resources [2]. Hydrologic system considered as integral portion of the universal climate regime. Therefore, the adverse impacts of global warming on water resources is mainly on the hydrological cycle by alter the evapotranspiration and air temperatures pattern [3].

Iraq confronts the climate change in all aspects of life particularly water sector [4]. The greater area of Iraq's land depends on the Tigris River and its tributaries for its living. The Greater Zab River (GZR) is largest Tigris tributary of water yield, its headwaters from Ararat Mountains of south-eastern Turkey then passes through the north of Iraq [5]. Risky weather events like droughts and variability in river discharge probably occur caused by global warming.

Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation report [6] at the global scale , indicate that since mid-20th century occurred the reduction in the number of cold days and rise the number of hot days moreover, anthropogenic effects have led to warming of extreme daily minimum and maximum temperatures. Climate models predict warming in temperature depending on emission scenario and the region, will expected rise approximately 1 to 3°C and 2 to 5°C by mid and end current century, respectively. Arab climate change assessment report [7] concluded that temperatures will increase over the Arab region during current century under the two RCP emission scenarios. Generally, the variation in temperature for RCP 4.5 demonstrates a rise of 1.2 °C–1.9 °C towards intermediate future period 2046–2065 and 1.5 °C– 2.3 °C at far future period 2081–2100. For scenario RCP 8.5, temperatures rise to 1.7 °C–2.6 °C by intermediate future period and 3.2 °C–4.8 °C during far future period. Nahlah et al. [3] Applied the Soil and Water Assessment Tool (SWAT) model and six climate model from General Circulation Model (GCM) under three emission scenarios: low emissions scenario (B1), scenario (A2) very high emissions and (A1B) medium emissions scenario. To assess the impact of climate change on Lesser Zab basin, northern Iraq for two period (2046-2064) and (2080-2100), results showed that temperature would rise. Mohamed M Nour El-Din (2013) [8] conceded study of Nile river basin, general circulation models (GCMs) predict the River Basin has become warmer, and the warming will continue in all probability. Abdullah Gokhan and Monzur Alam [9] presented a comprehensive review to previous studies that related to impact climate change on water resources and its future effect in Turkey. Concluded that future streamflow would reduce in Turkish water basins, temperature will rise by (2-6) ° C and most areas in Turkey (southern, western and Eastern).

The Present study aims to analyses forecasts of average air temperatures by utilizing regional climate model (RCA4) from Coordinated Regional Climate Downscaling Experiment (CORDEX) under scenarios of emission greenhouse RCP 4.5 and RCP 8.5. The Middle East and North Africa (MENA) region adopted to acquire forecasted long term daily air temperature over GZR basin at mid-21st century (2047-2073) and end-21st century (2074-2100) periods. The daily air temperature for the observed period (1979-2005) were obtained from Water and Global Change (WATCH). The daily, monthly and seasonally analysis were used to future evaluate of air temperatures over study basin, which would assistance decision makers to take procedures to overcome, mitigate and adaptation of water scarcity within the basin.

2. Study Area Description

The Grater Zab River (GZR) is the largest Tigris tributary regarding of water income. The basin area of GZR is shared between two countries, 65% from it is located in Iraq and 35% in Turkey. Its main source in the Ararat Mountains of south-eastern Turkey then passes through the north of Iraq [5]. Study area is located geographically in the east Mediterranean zone, bound by Iran in the east and Syria in the west figure (1). GZR Basin at Eski-Kalak gauging station is covered area 20435 km^2, bounded by latitude 36° 5′- 38° 17′ N, and longitude 43° 7′- 44° 53′ E. The Basin is distinguished with high mountainous, terrain surface generally increases in elevation from 240 m to 4000 m a.s.l. figure (2) towards north and northeast [10]. The winter season is cool, with average air temperature about 5 °C to 10 °C, whereas in summer is hot in some days temperatures reach 45 °C or more [11].

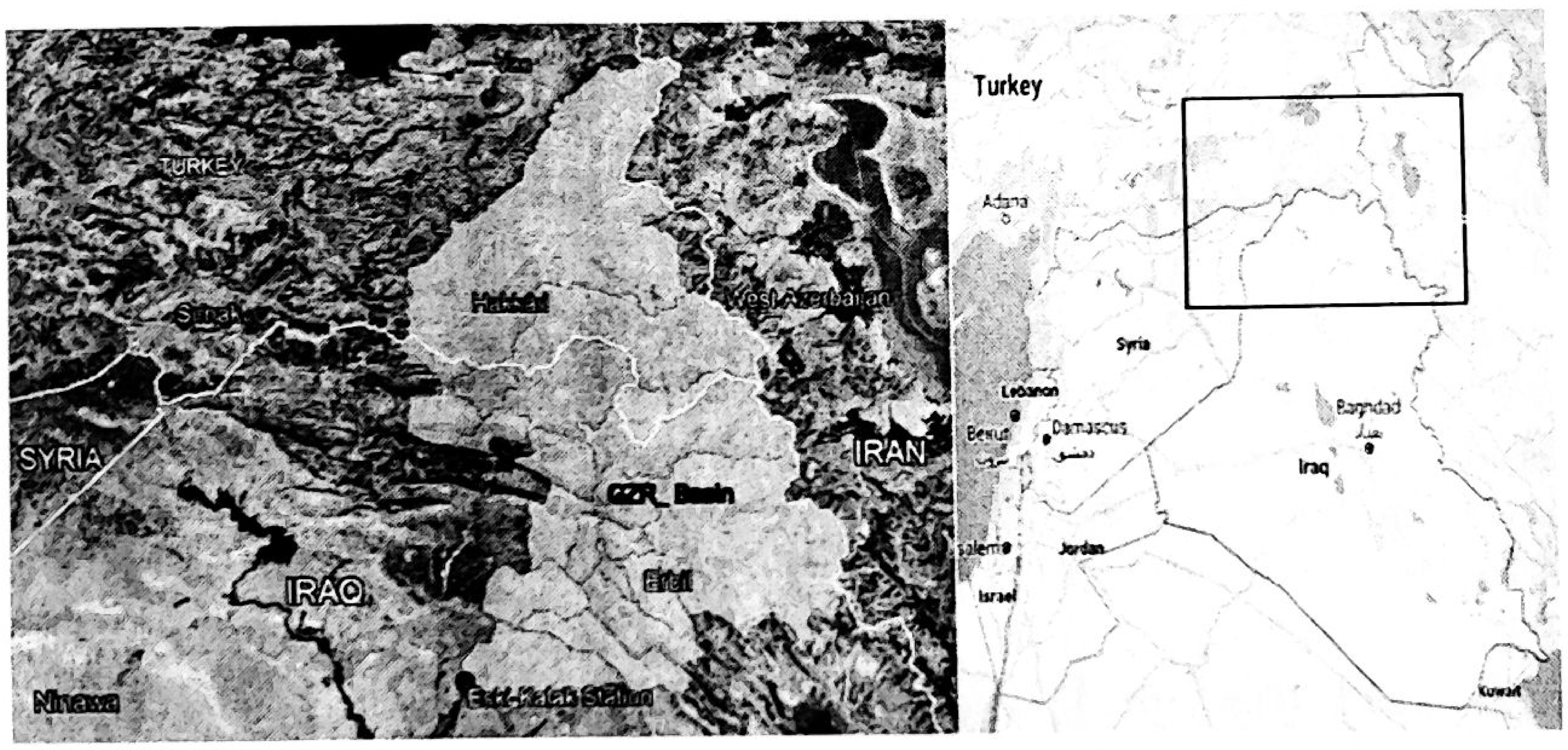

Figure 1. The Location of Greater Zab River Basin

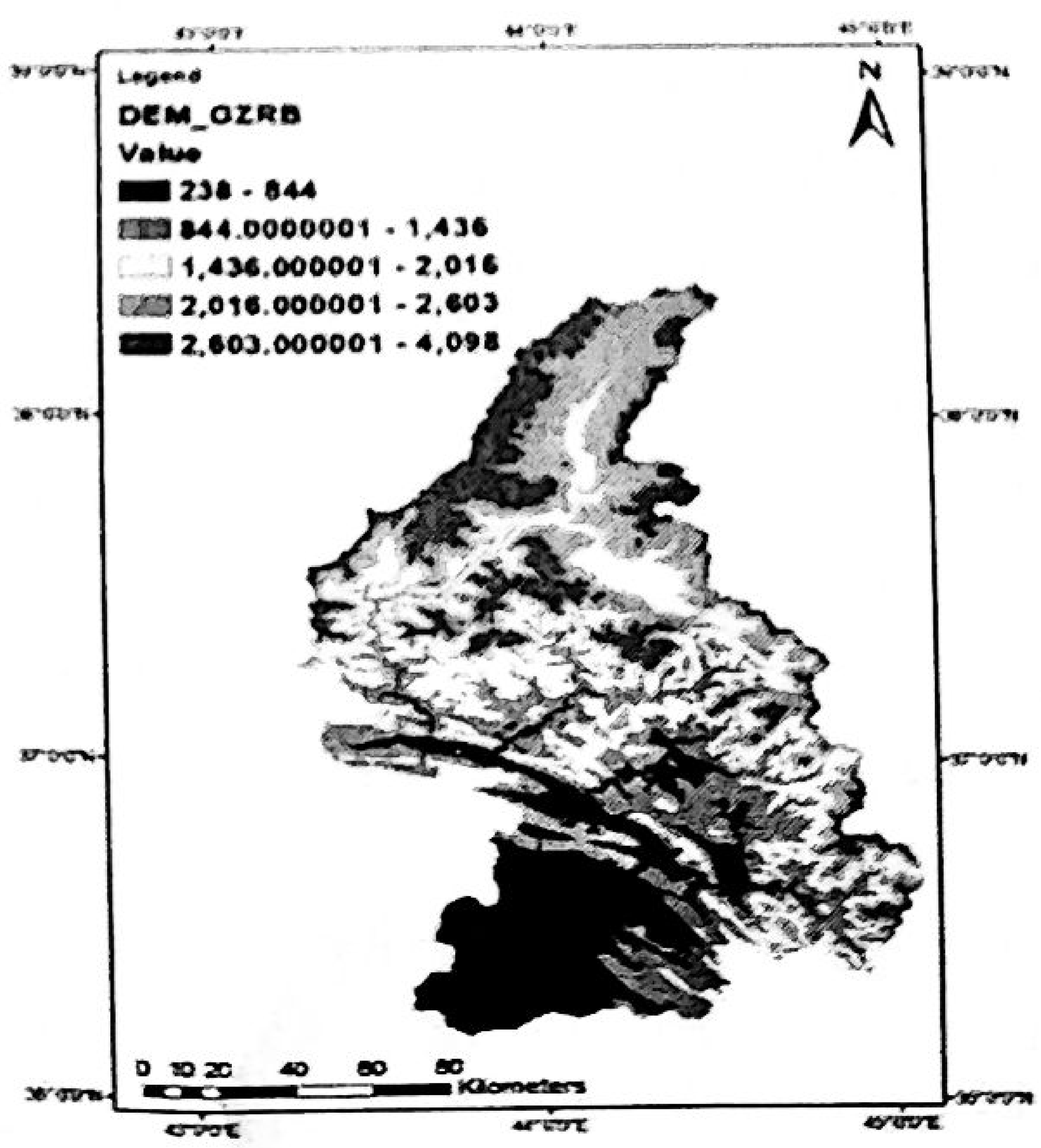

Figure 2. Digital Elevation Model (DEM) of GZR basin

3. Methodology

3.1 Data Preparation

In the present study, the observed data have been obtained from (WFDEI) is WATCH Forcing Data methodology applied to ERA-Interim data and exist in Water and Global Change (WATCH) website for period (1979-2005) [12]. All WFDEI data files contain grid-cell center longitude and latitude with 0.5° x 0.5° resolution and distributed over entire study area. Network Common Data Format (NetCDF) is type of all WFDEI files, therefore, Grid Analysis and Display System (GrADS) software [13] employed to convert data files to excel format. The projections of daily average air temperatures over GZR basin under impact of global climate change were gained by utilizing Regional Climate Downscaling (RCD) techniques. Coordinated Regional Climate Downscaling Experiment (CORDEX) employed for this aim, with two emissions scenarios and concentrations of greenhouse gases (RCP 4.5) and (RCP 8.5).

3.2 Regional Climate Model

The World Climate Research Programme (WCRP) is organization, aims to analysis, simulate and future predicts of global system climate change, additionally study of population activities impact on future climate system. WCRP instituted at 1980 and existing in Geneva, Switzerland [14] . Coordinated Regional Climate Downscaling Experiment (CORDEX) is programme under WCRP. CORDEX provides climate information for high-resolution at each grid cell with scale 0.44° x 0.44° approximate 50 x 50 kilometers. The statistical downscaling uses empirical relations between large-scale characteristics and local cases assuming that these relationships remain the same in an altering climate. The dynamical downscaling makes use of Regional Climate Models (RCMs) that are set up on a smaller-scale at higher resolution compared to the General Circulation Models (GCMs).

CORDEX is utilized both Regional Climate Models (RCMs) and Empirical Statistical Downscaling (ESD) to downscaled local climate data over a domain and driven from a set of General Circulation Models through the multi-model is Coupled Model Intercomparison Project Phase 5 (CMIP5) [15]. To download CORDEX climate data (forecast and historical periods) from Earth System Grid Federation (ESGF) for Greater Zab River basin were utilized Li.U NSC-SMHI is one of ESGF-CoG data nodes [16]. Middle East North Africa (MENA) is one of CORDEX domains was selected because the study area located within it and the Mediterranean cyclones effect it, figure (3). Download daily average surface temperature (tas), with two experiments of Representative Concentration Pathways to represent future scenarios of emissions and concentrations for greenhouse gases and aerosols. These scenarios are depended on a various approach and contain more consistent short-lived gases and land use variations [17]. Using the medium radiative scenario reach to 4.5 W/m^2 (RCP 4.5) assume stabilizing of emission after year 2100 and high radiative scenario at value 8.5 W/m^2 (RCP 8.5) assume increasing emission scenario after 2100 figure (4). The regional climate model that used in this study is (RCA4) developed by Swedish Meteorology and Hydrological

Institute (SMHI). RCA4 is the latest version of the Rossby Center Regional Atmospheric model and can be employed for any domain worldwide. RCA4 model depend on the numerical weather prediction model HIRLAM [18]. Applied the ensemble (r12i1p1) and employed the General Circulation Model (GCM) is (ICHEC-EC-EARTH) as a driving model.

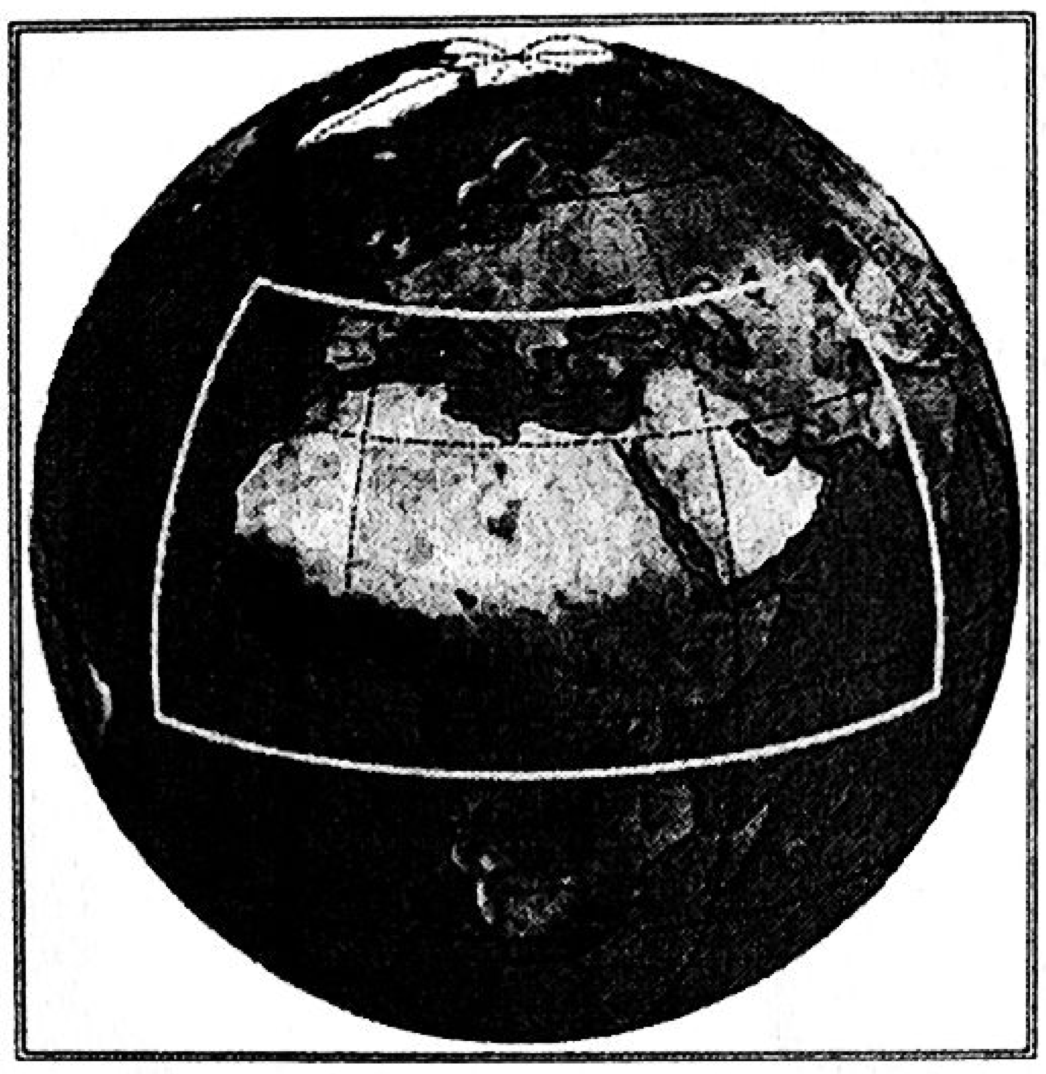

Figure 3. Middle East North Africa (MENA) Domain [15]

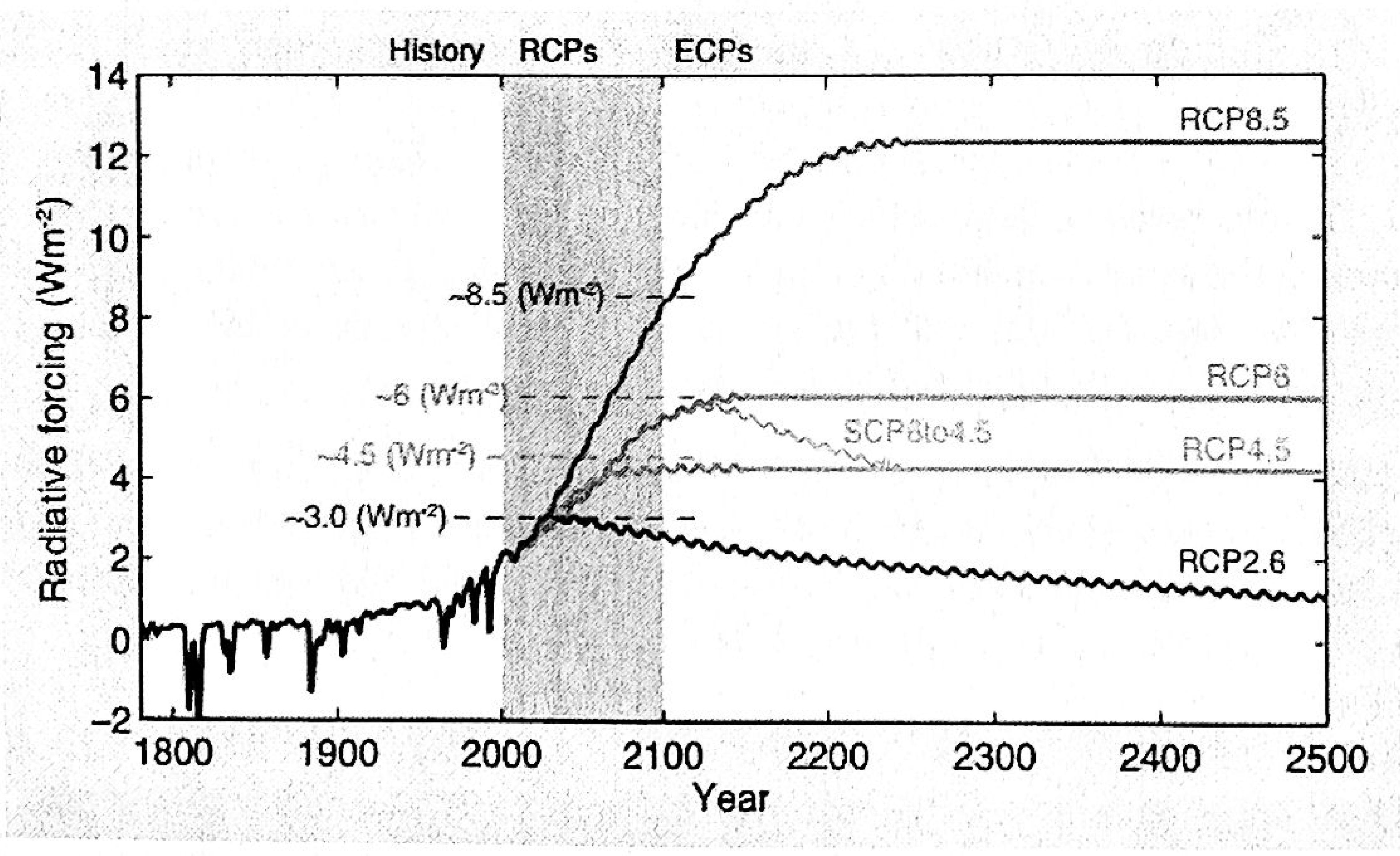

Figure 4. Representative Concentration Pathways (RCP) scenarios [17]

3.3 Bias Correction Approach

The raw outputs from Regional Climate Models (RCM) still include substantial bias, which is inherited from the effect of General Circulation Models (GCMs) or generated via systematic model mistake [19]. These biases appear when comparing between observed data and historical simulation outputs (hindcasted period) from RCMs. The purpose from bias correction is to remove or reducing statistical biases from the forecast datasets [20]. Bias correction approach is necessary in climate impact studies because low calculation request, flexibility and the capacity to improve the match between historical data from RCM and observations. Bias correction technique is assumed to be stationary with time, its meaning the correction algorithm and its parameterization for present climate situations are valid for future situations as well [21]. The schematic of bias correction between observation and climate model data represent in figure (5).

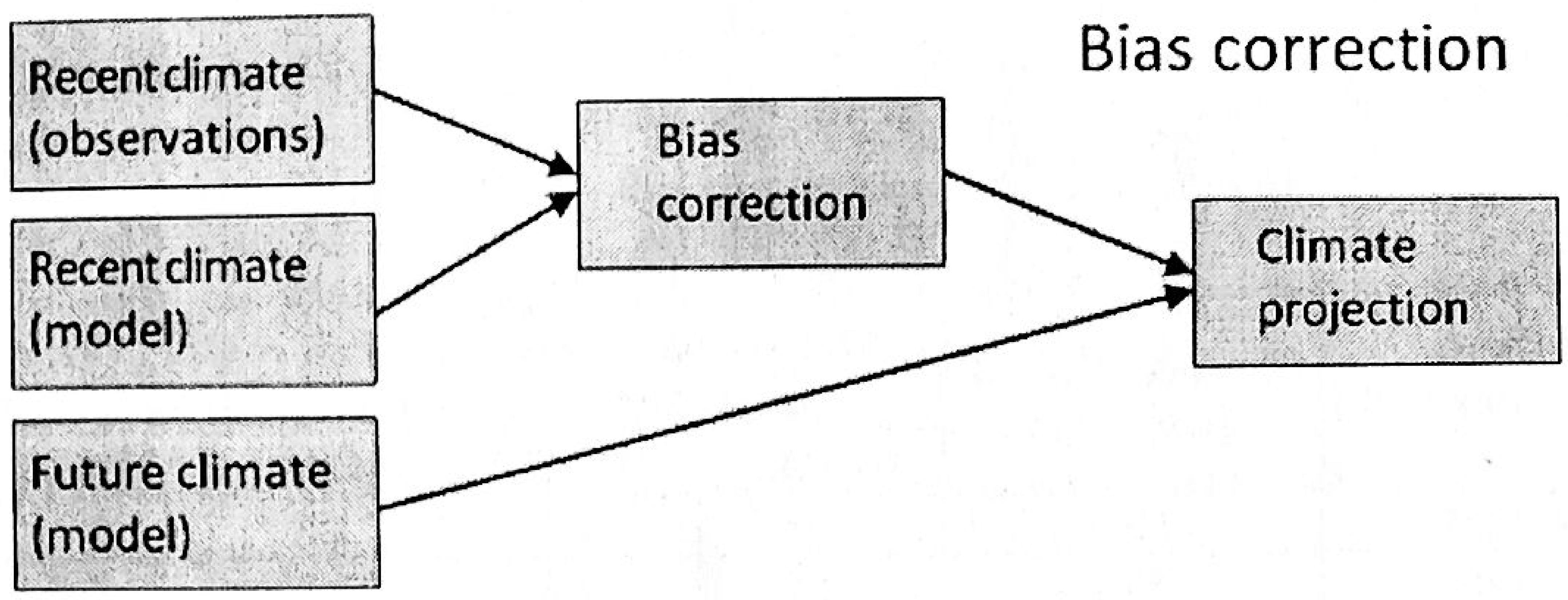

Figure 5. A schematic representation of bias correction approach [22]

For current study, bias correction approach were conducted of average daily air temperature data from regional climate model RCA4 by employing equation (1) [23]. Data periods of bias correction were the observed, historical climate model (1979-2005) and future climate model for two mid- 21st century (2047-2073) and end- 21st century (2074-2100) under two emission scenarios RCP4.5 and RCP8.5.

$$T_{BC}(t) = \bar{O}_{REF} + \frac{\sigma O_{REF}}{\sigma T_{REF}}(T_{RAW}(t) - \bar{T}_{REF}) \qquad (1)$$

Where $T_{BC}(t)$ is projected future daily temperature, $\bar{O}_{REF}$ and $\bar{T}_{REF}$ are average daily temperature of observed and historical climate model, respectively, σO_{REF} and σT_{REF} are standard deviation of the daily observations and historical model, respectively, and $T_{RAW}(t)$ is daily temperature of scenario climate model.

4. Results and discussions

In this study, the daily average air temperatures analysis have been conducted for both the observed period covered 1979-2005 and the prediction period which divided to two sub periods: near future 2047-2073 and distant future 2074-2100 under medium and high emission scenarios. Table (1) presents the average annually of number hot and cold days for seven categories of temperature between less than -4 °C to more than 30 °C for observed and future periods. The results demonstrated that during forecasted periods under both emission scenarios will be decrease a number of cold days whereas, increasing a number of hot days relative to the observed period. Figures (6) and (7) represent probability density function (pdf) of average daily temperature for study periods with medium and high emission scenario, respectively, eighteen bins are considered in generating histograms. In general, during prediction periods the frequency of events at temperature higher than 12 °C were more occurrence compared with the observed period Conversely for events that less than 12 °C. The maximum, mean and minimum daily air temperature during observed period and future periods at two emission scenarios over the basin were represented in figures (8), (9) and (10), respectively. Table (2) summarized the higher and lower values for maximum, minimum and mean daily air temperature for these periods.

Table 1. Average annually of hot and cold days

Mean temperature (°C)	Number Days				
	Observed period 1979-2005	Mid-century (bias corrected) 2047-2073		End-century (bias corrected) 2074-2100	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
t <= -4 degC	15.5	1.9	1.0	1.0	0.5
t <= -2 degC	33.7	12.9	7.6	7.7	2.0
t <= 0 degC	57.7	37.1	28.5	30.0	10.6
t >= 5 degC	248.1	261.1	268.9	264.4	280.1
t >= 10 degC	201.3	217.9	224.4	222.9	240.0
t >= 20 degC	105.2	130.9	145.6	135.4	164.7
t >= 30 degC	0.5	2.7	10.4	5.0	35.1

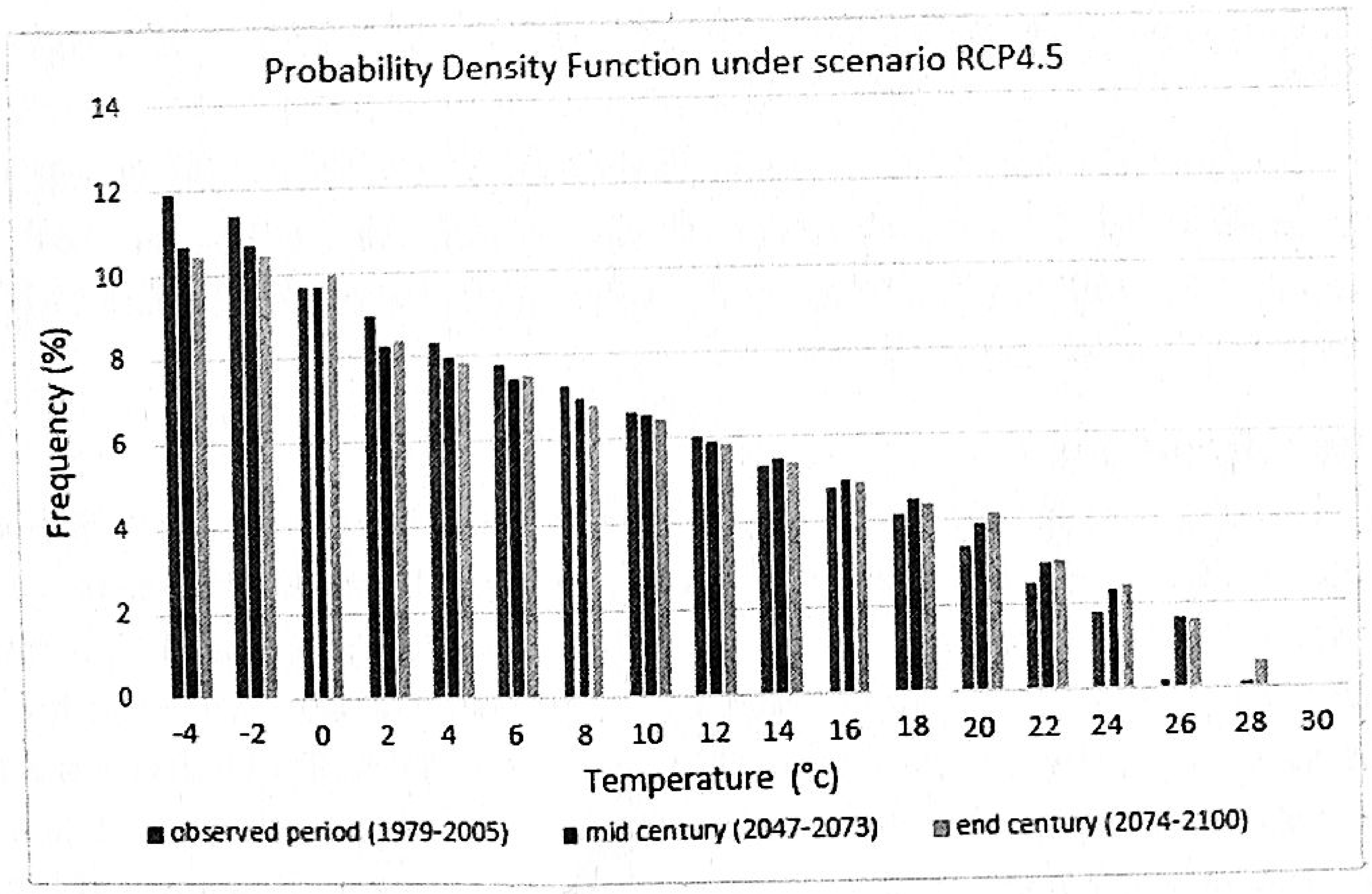

Figure 6.

Probability density function (pdf) of average daily temperature at medium scenario.

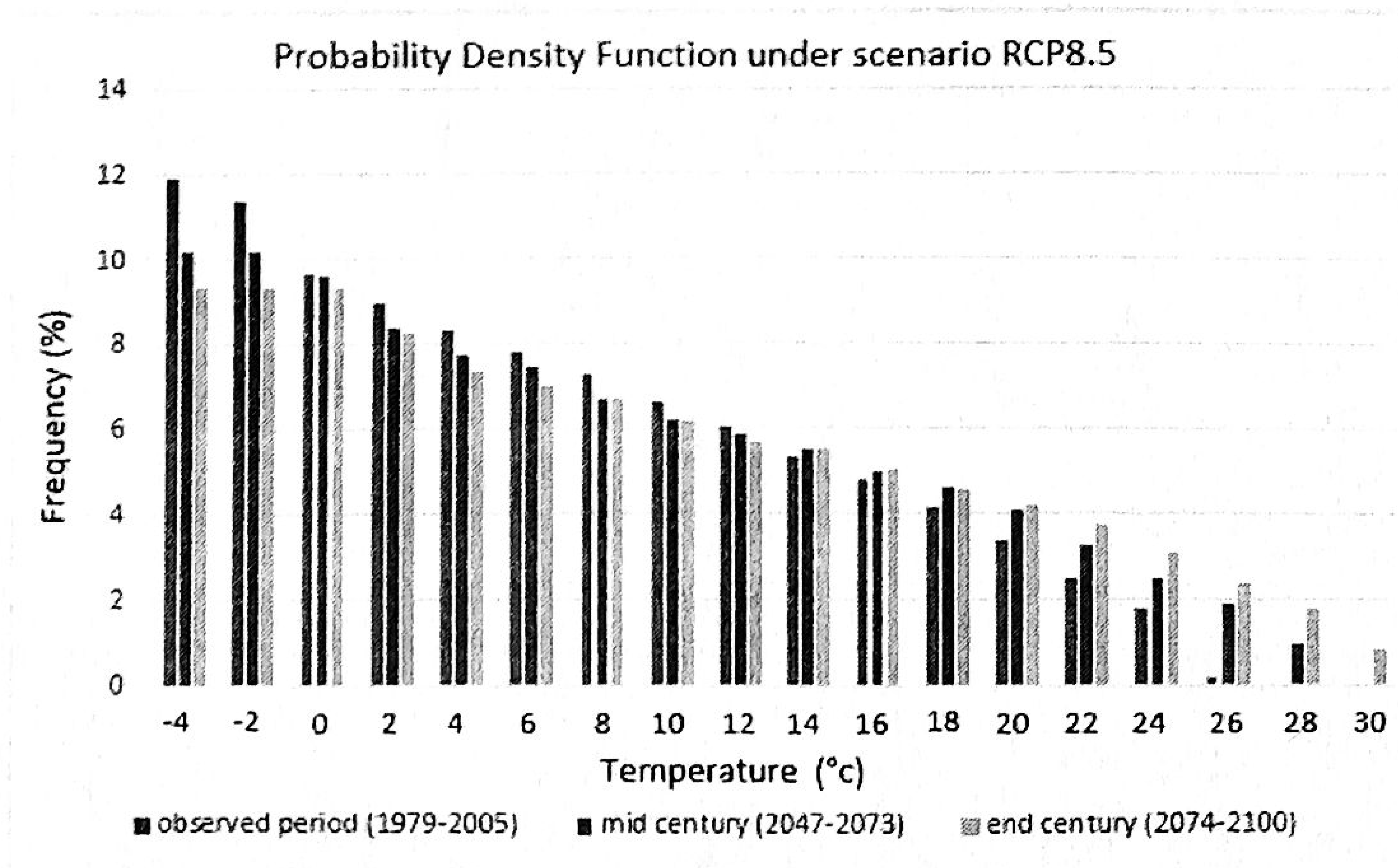

Figure 7. Probability density function (pdf) of average daily temperature at high scenario.

The results appeared that Possibility of occurrence extreme values in maximum daily temperatures at prediction period moreover, these values will be rise under high emission scenario (RCP8.5) more than medium scenario (RCP4.5). During observed period the high value of maximum daily temperature was 31.37 °C in 2001 whereas the temperatures are expected reach to 32.7 °C in year 2055 and 35.5 °C in year 2094 under scenario RCP4.5 and RCP8.5, respectively. In end-century period at RCP 4.5 and mid-century period at RCP 8.5 the average daily temperatures were more variability compared other periods. Regarding minimum daily temperatures, during observed years the lower value was -12.15 °C in 1983 while in prediction years at RCP4.5 and RCP8.5 were -7.36 °C in 2096 and -7.42 °C in 2047, respectively. Generally, the minimum daily temperatures of future periods will be high relative to the observed period.

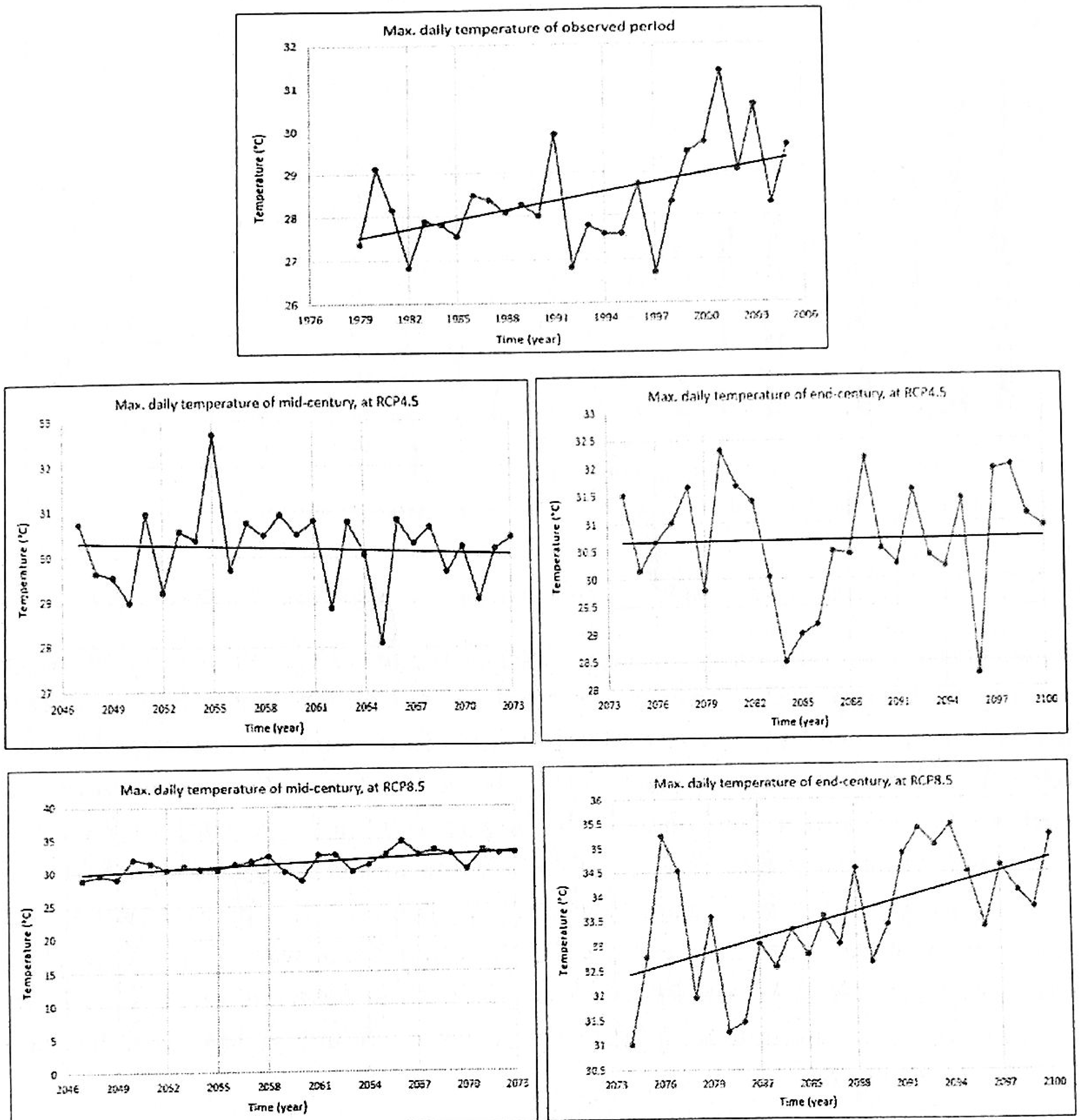

Figure 8.

Maximum daily temperatures for observed and prediction periods of the basin.

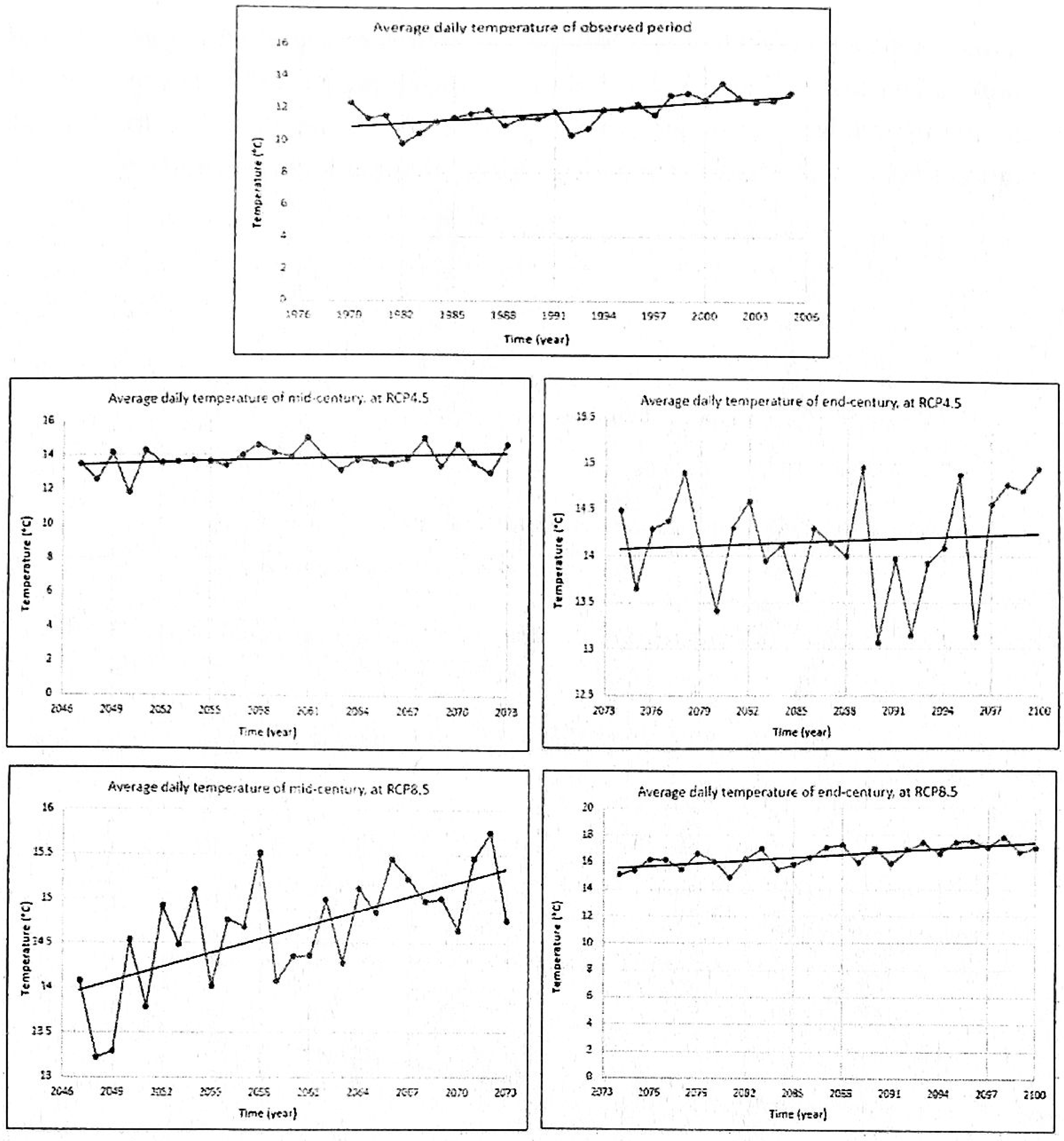

Figure 9. Average daily temperatures for observed and prediction periods of the basin.

In current study, the analysis of average monthly air temperatures were performed to determine the change amounts between observed and predicted periods. Figure (11) shows an increasing in average monthly temperature over GZR basin during the mid and end-century periods under medium emission scenario relative to the observed period, these values varied between the minimum in January and maximum in July as follows: (-0.5, 27.2), (0, 28) and (-1.94, 25.3) °C, respectively. Furthermore, under high emission scenario the outputs from regional climate model showed warmer will be occur over the basin compared the observed period. The fluctuations of average monthly temperatures between the lowest in January and highest in July about (0, 28.67) and (1.55, 30.65) °C for mid and end century periods, respectively figure (12).

Analysis of averages seasonally conducted by employing four season are: winter season (DJF) includes the months December, January and February, spring season (MAM) represents the months March, April and May, summer season (JJA) consists the months Jun, July and August and autumn season comprises a month September, October and November.

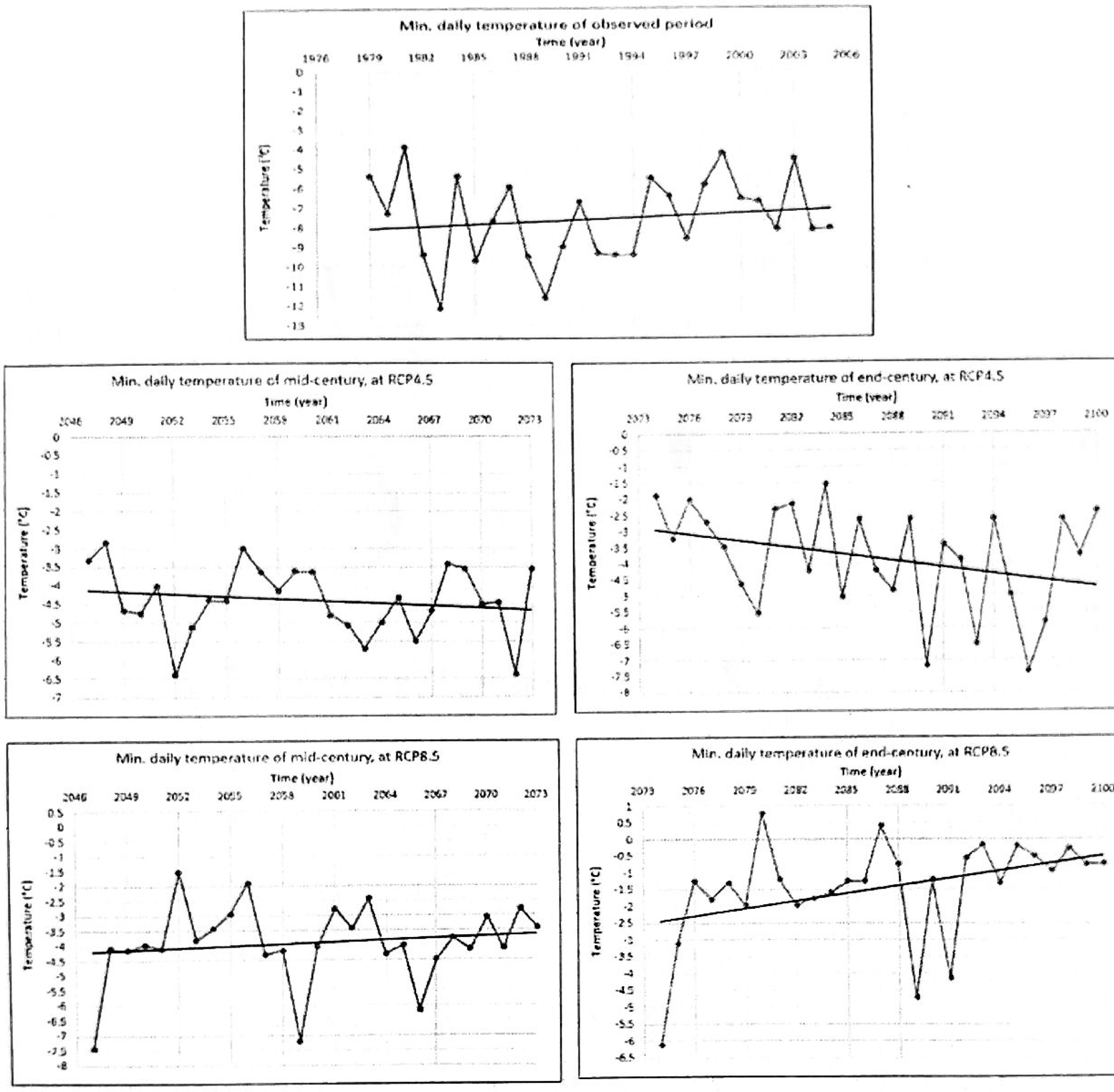

Figure 10. Minimum daily temperatures for observed and prediction periods of the basin.

Table 2. Higher and lower values for maximum, minimum and average daily temperatures (°C) during study periods

Daily Temperatures	parameter	observed period	mid-century		end-century	
			RCP4.5	RCP8.5	RCP4.5	RCP8.5
maximum value of each year	higher	31.37	32.71	34.73	32.31	35.47
	lower	26.68	28.09	28.83	28.25	31.01
minimum value of each year	higher	-3.84	-2.85	-1.53	-1.55	0.78
	lower	-12.15	-6.40	-7.42	-7.36	-6.11
average value of each year	higher	13.52	15.01	15.75	14.96	17.84
	lower	9.84	11.78	13.22	13.07	14.87

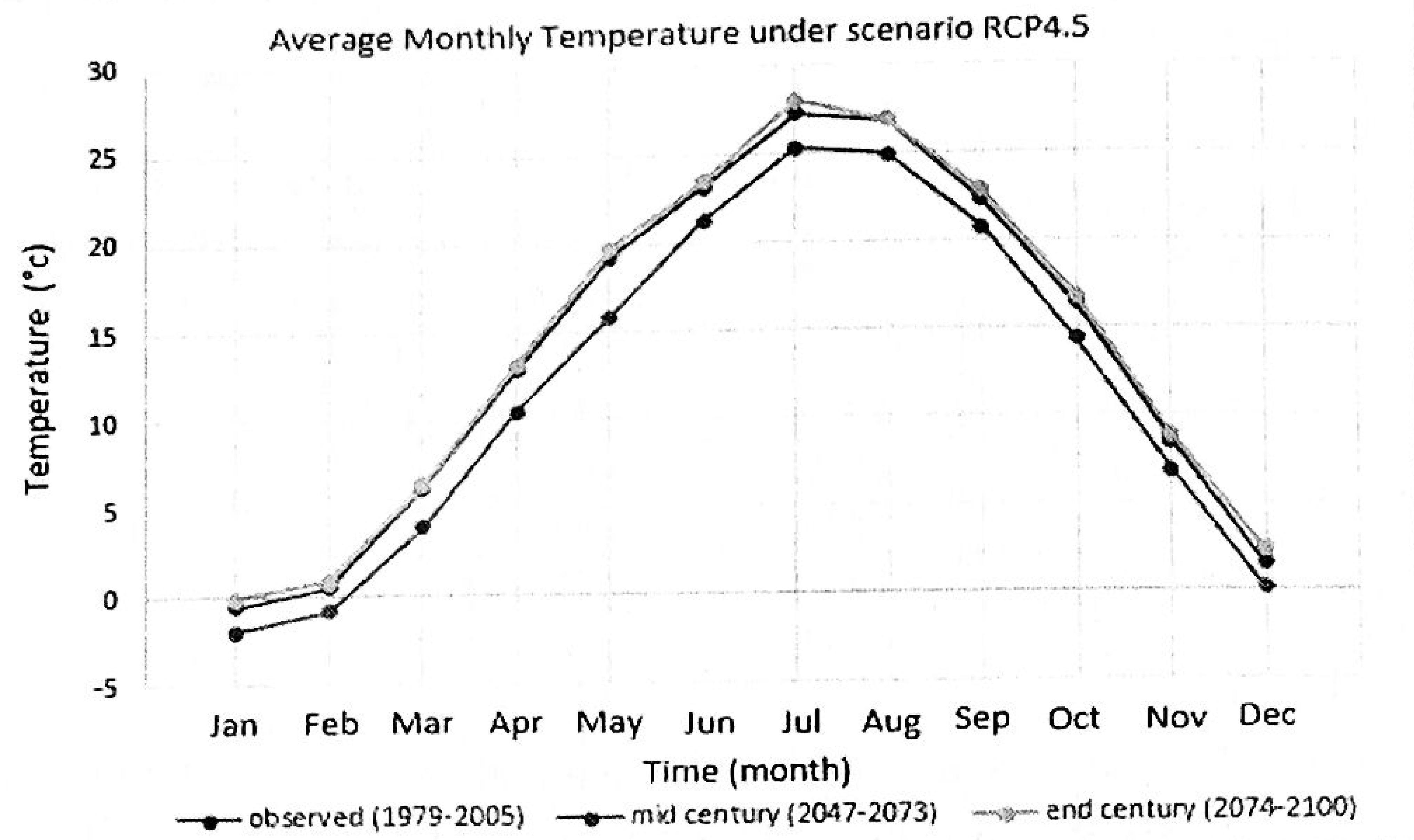

Figure 11. Change of average monthly temperature over Greater Zab basin at medium scenario.

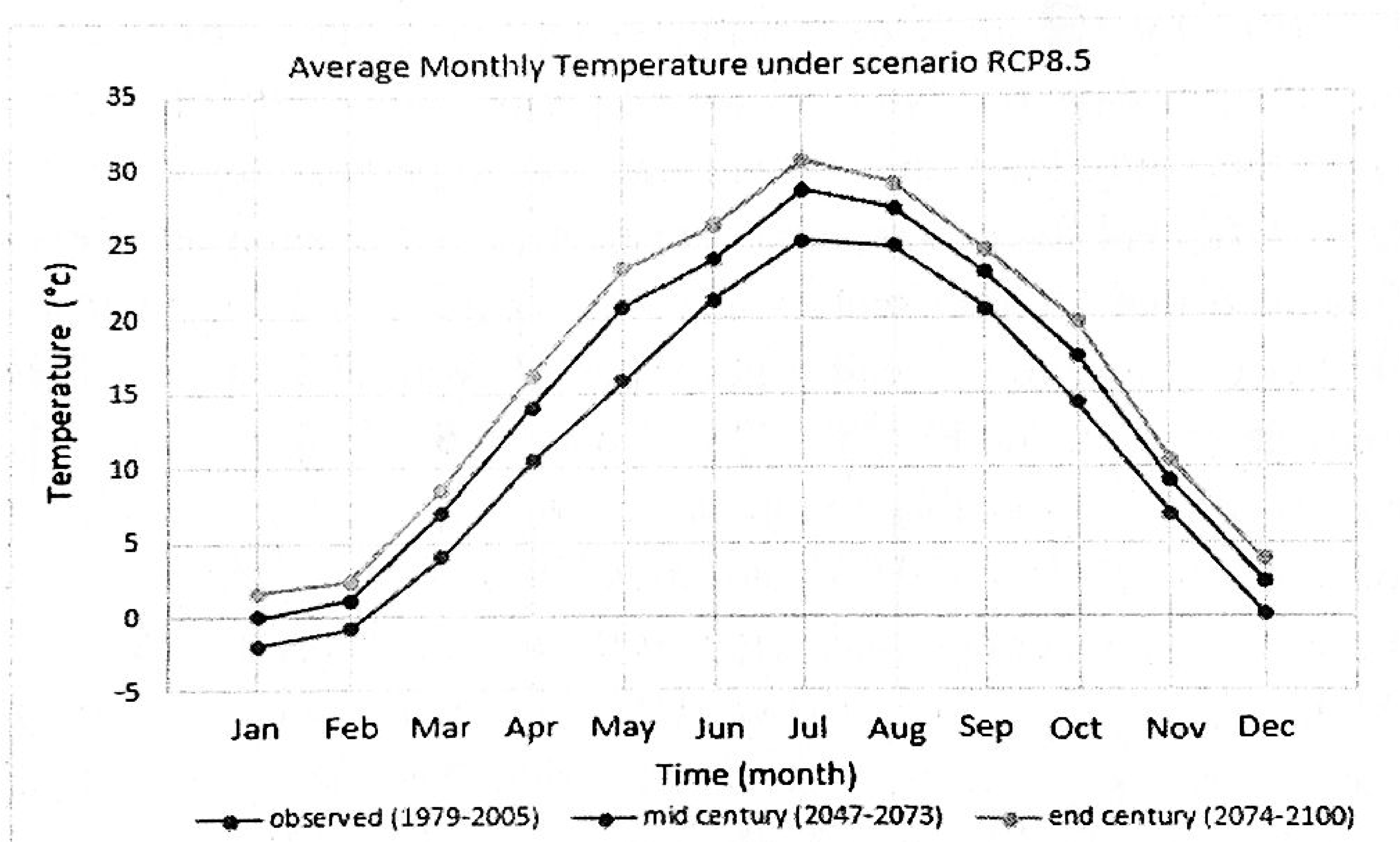

Figure 12. Change of average monthly temperature over Greater Zab basin at high scenario.

Table (3) summarized the average seasonally and annually of air temperatures for study periods, during prediction periods the four seasons showed warmer in temperatures relative to the observed period. During scenario RCP4.5, the increasing in average annually temperature at mid and end-century period reach to 1.92 and 2.35 °C, respectively whereas, for scenario RCP8.5 approximately were 2.84 and 4.64 °C for mid and end century periods, respectively. At both emission scenarios, the average annually of temperatures bias (°C) for prediction periods compared the observed period have been displayed in gridded maps, figure 13.

Table 3. Average seasonal of air temperatures at observed and future periods over the basin.

Season	Mean Temperature (°C)				
	Observed period 1979-2005	Mid-century (bias corrected) 2047-2073		End-century (bias corrected) 2074-2100	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
DJF	-0.85	0.52	1.17	1.04	2.57
MAM	10.07	12.72	13.95	13.09	16.03
JJA	23.79	25.72	26.69	26.07	28.70
SON	13.93	15.66	16.51	16.15	18.22
Annual	11.74	13.65	14.58	14.09	16.38

5. Conclusion

In current study, the daily, monthly and seasonally data of average air temperatures were examined over greater zab river basin for observed period (1979-2005) and two forecasted (2047-2073), (2074-2100) periods under medium and high emission scenarios. The results from RCA4 regional climate model demonstrated a rising in average air temperatures during the prediction periods compared the observed period owing to global warming. For both medium and high emission scenarios, decreasing the average annually of number of cold days while, increasing the hot days relative to observed period. Possibility of occurrence extreme temperatures over the study basin at mid and end future periods approximately 32.71 and 35.47 °C under RCP4.5 and RCP8.5 scenarios, respectively. The analysis of average monthly temperatures indicated that the maximum value was recorded in July month by 25.3 °C for observed period but during mid and end century periods was 27.2 and 28 °C under RCP4.5 scenario, whereas at scenario RCP8.5 was 28.67 and 30.65°C, respectively. Regarding the minimum value of average monthly temperatures was in January month about -1.94 at observed period but during (2047-2073) and (2074-2100) future periods was -0.5 and 0 °C under medium scenario while at high scenario was 0 and 1.55 °C, respectively. The outcomes demonstrated high temperature in four seasons DJF, MAM, JJA and SON through the future period at both scenarios compared to the observed period. The increasing in average annually temperature under scenario RCP4.5 would reach to 1.92 and 2.35 °C relative to the observed period whereas, at scenario RCP8.5 will be approximately 2.84 and 4.64 °C during near and distant future periods, respectively. High temperature will be negative effect on water resources and water availability moreover, reduced plant growth and productivity. Consequently, some strategies must be adopted to mitigate the impact of global warming over the greater zab river basin in future.

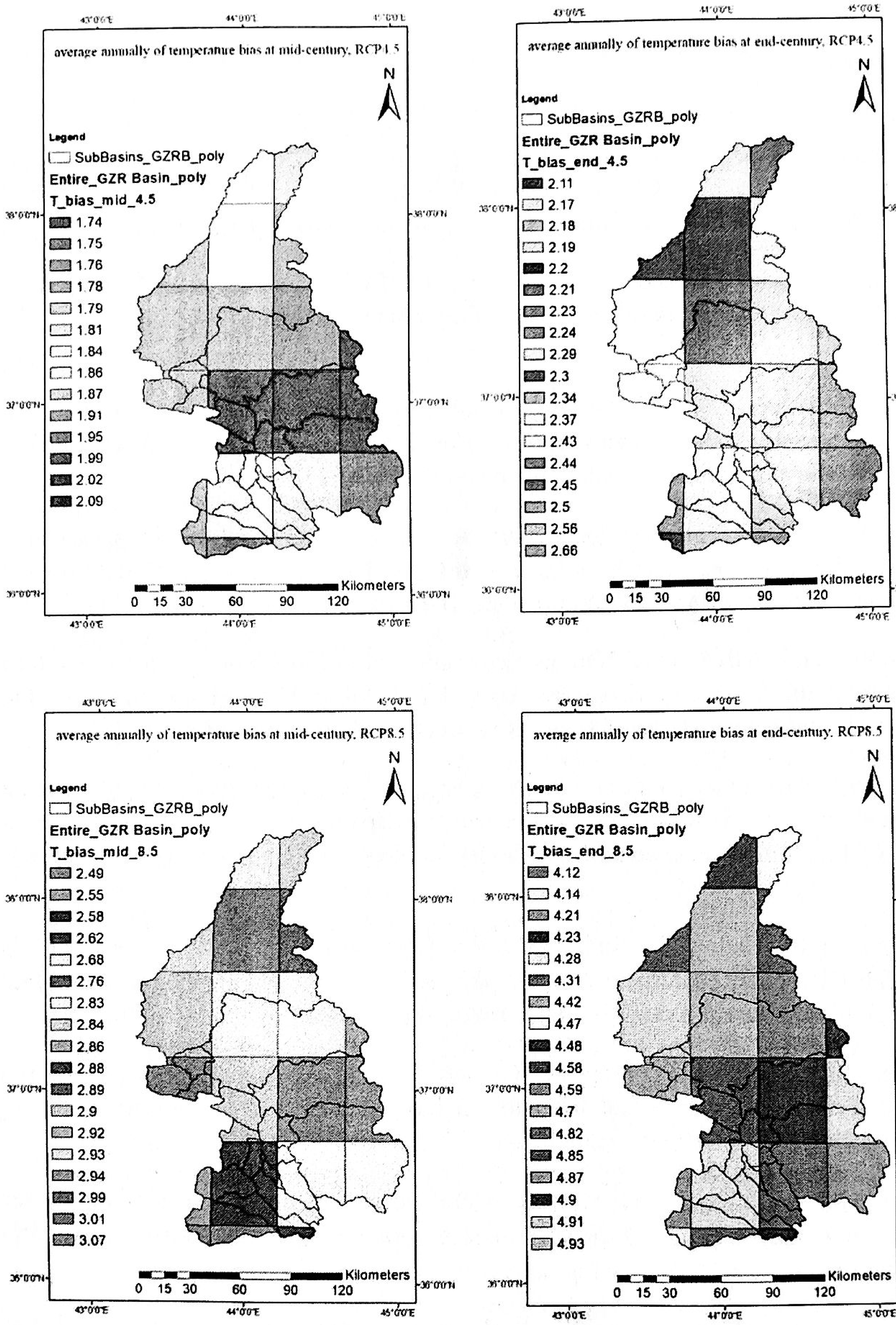

Figure 13. Spatial distribution of average annually of temperatures bias (°C) for future periods under both scenarios

6. References

[1] Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, "Climate Change 2014, Synthesis Report," the Intergovernmental Panel on Climate Change, Geneva , Switzerland, 2015.

[2] Kumar S., Himanshu S.K. and Gupta K.K., "Effect of Global Warming on Mankind - A Review," *International Research Journal of Environment Sciences,* vol. 1, no. 4, pp. 56-59, 2012.

[3] Nahlah Abbasa,Saleh A. Wasimia and Nadhir Al-Ansari, "Assessment of Climate Change Impact on Water Resources of Lesser Zab, Kurdistan, Iraq Using SWAT Model," *Scientific Research Publishing*, vol. 8, pp. 697-715, 2016.

[4] Nahlah Abbas, Saleh A Wasimi and Nadhir Al-Ansari, "Assessment of Climate Change Impacts on Water Resources of Khabour in Kurdistan, Iraq Using SWAT Model," *Journl of Invironmental Hydrology*, vol. 24, pp. 1-21, 2016.

[5] UN-ESCWA and BGR (United Nations Economic and Social Commission for Western Asia; Bundesanstalt für Geowissenschaften und Rohstoffe), "Shared Tributaries of the Tigris River," Inventory of Shared Water Resources in Western Asia., Beirut., 2013.

[6] IPCC, Intergovernmental Panel on Climate Change , "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation report," Intergovernmental Panel on Climate Change , Cambridge University Press, the United States of America, 2012.

[7] (ESCWA), United Nations Economic and Social Commission for Western Asia, "ARAB CLIMATE CHANGE Assessment Report," By the United Nations Economic and Social Commission for Western Asia (ESCWA)., Beirut, Lebanon, 2017.

[8] Mohamed M Nour El-Din, "Proposed Climate Change Adaptation Strategy for the Ministry of Water Resources and Irrigation in Egypt," UNESCO-Cairo Office,, Cairo, 2013.

[9] Abdullah Gokhan Yilmaz and Monzur Alam Imteaz, "Climate change and water resources in Turkey: A review," *International Journal of Water,* vol. 8, no. 3, pp. 299-313, 2014.

[10] Varoujan K. Sissakian, Talal H. Kadhim and Mawahib F. Abdul Jab'bar, "GEOMORPHOLOGY OF THE HIGH FOLDED ZONE," *Iraqi Bull. Geol. Min.* , no. 6, pp. 7-51, 2014.

[11] UNDP, "Draft Final Report for Capacity Assessment for," Jordan, 2012.

[12] *www.eu-watch.org/data_availability,* version: 18th September 2013.

[13] *https://sourceforge.net/projects/opengrads/files/grads2/2.0.2.oga.1/Windows/,* 2020.

[14] *https://www.wcrp-climate.org/,* 2020.

[15] *https://cordex.org/,* 2020.

[16] *https://esg-dn1.nsc.liu.se/search/esgf-liu/,* 2019.

[17] Intergovernmental Panel on Climate Change, "Climate Change 2013 The Physical Science Basis," Cambridge University Press, the United States of America, 2013.

[18] Gustav Strandberg, Lars Bärring, Ulf Hansson, Christer Jansson, Colin Jones, Erik Kjellström, Michael Kolax, Marco Kupiainen, Grigory Nikulin, Patrick Samuelsson, Anders Ullerstig and Shiyu Wang , "CORDEX scenarios for Europe from the Rossby Centre regional climate model RCA4," Swedish Meteorological and Hydrological Institute (SMHI), Norrköping, Sweden, 2014.

[19] Min Luo , Tie Liu , Fanhao Meng , Yongchao Duan , Amaury Frankl , Anming Bao and Philippe De Maeyer, "Comparing Bias Correction Methods Used in Downscaling Precipitation and Temperature from Regional Climate Models: A Case Study from the Kaidu River Basin in Western China," *Water,* vol. 10, no. 1046, pp. 1-21, 2018.

[20] Levi Brekke, Bridget L. Thrasher, Edwin P. Maurer and Tom Pruitt, "Downscaled CMIP3 and CMIP5 Climate Projections," http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/., 2013.

[21] Delei Li, Jianlong Feng, Zhenhua Xu, Baoshu Yin, Hongyuan Shi and Jifeng Qi, "Statistical Bias Correction for Simulated Wind Speeds Over CORDEX-East Asia," *Earth and Space Science,* vol. 10.1029/2018EA000493, pp. 200-211, 2019.

[22] Olle Raty, Jouni Raisanen and Jussi S. Ylhaisi, "Evaluation of delta change and bias correction methods for future daily precipitation: intermodel cross-validation using ENSEMBLES simulations," *Clim Dyn,* vol. 42, p. 2287–2303, 2014.

[23] Ed Hawkins, Thomas M. Osborne, Chun Kit Ho, and Andrew J. Challinor, "Calibration and bias correction of climate projections for crop modelling: An idealised case study over Europe," *Agricultural and Forest Meteorology,* vol. 170, p. 19–31, 2013.