Study of the Process of Climate Change According to Data Simulation Using LARS-WG Software during 2010-2030: Case Study of Semnan Province

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Abstract**—**Temperature rise on Earth has had harmful effects on the Earth's surface and has led to change in precipitation patterns all around the world. The present research was aimed to study the process of climate change according to the data simulation in future and compare these parameters with current situation in the studied stations in Semnan province including Garmsar, Shahrood and Semnan. In this regard, LARS-WG software, $HADCM_3$ model and A_2 scenario were used for the 2010-2030 period. In this model, climatic parameters such as maximum and minimum temperature, precipitation and radiation were used daily. The obtained results indicated that there will be a 4.4% increase in precipitation in Semnan province compared with the observed data, and in general, there will be a 1.9% increase in temperature. This temperature rise has significant impact on precipitation patterns. Most of precipitation will be raining (torrential rains in some cases). According to the results, from west to east, the country will experience more temperature rise and will be warmer.

Keywords**—**Climate change, Semnan province, LARS-WG model, climate parameters, $HADCM_3$ model

I. Introduction

THERE is a period of time that climate change has been paid attention by societies and researchers. The impacts of climate changes on the environment and societies are comprehensive and complicated so that agricultural areas, seasonal access to water resources and volume of the available water are variable from place to place and shortages will be intensified [1]. The application of two models, LARS-WG and ClimGen, in simulation of meteorological variables in Iran indicated that the LARS-WG model has had better performance in simulation of precipitation and radiation, but ClimGen has had better performance in temperature changes [2]. According to the conducted studies on climate changes in South Korea (2010-2039) with the application of the LARS-WG model, the amount of precipitation will increase in the future in general but it has relative loss in late 2010. In addition, the average temperature will increase in future decades compared with the past.

The practicability of the abovementioned models was investigated in 18 stations of America, Europe and Asia and the obtained results indicated that the LARS-WG model has more compatibility with the observed data compared with the WGEN model [3].

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The impact of climate change on frequency of floods was studied using the output of general circulation models of atmosphere ($HADCM_3$) under A_2 scenario and the results showed that there was increase in frequency of floods in most of the periods of return although there was decrease in average precipitation in the under study regions [4]. Climate change has positive effects on agricultural products in some of the countries in the world, especially those located in northern latitudes higher than 55°, on the contrary, it has severe effects in warm and dry areas so that increasing temperature and decreasing rainfall will be more intense in developing countries and thereby the severity of the climatic phenomenon (drought, heat and cold and floods) will be increased [5]. In addition, climate change and increasing temperature could lead to reduction of agricultural production in regions with tropical climate. Therefore, increase in temperature has impact on evapotranspiration, humidity and rainfall. Moreover, it leads to increase in water consumption [6]. This increasing temperature resulted from climate change has been forecasted in many of the countries, hence, according to the selected model and scenario, its amount and presented results are somehow different with each other. The extent of changes in temperature will be different in different regions so that there will be more increase in temperature whatever we move to the east. The results of some of the conducted studies indicated that the impact of climate change on increase in temperature is generally led to rise in temperature during the night. In fact, temperature in night is more affected by climate change than temperature in the day do [7].

Most of the researchers believe that since regions located in mid-latitudes (15° to 40°) experience considerable increase in temperature and reduction of precipitation, drought indices are the most appropriate criteria in order to evaluate the regional effects of climate change in these areas. Based on the existing evidences, the extent of drought in tropical and subtropical is of characteristics of the future climate [8].

The effect of climate change on the environment and society is complicated and pervasive that in agricultural context, it will influence seasonal access to water resources and the amount of agricultural products and will intensify shortages. Numerical simulation with climate models is an important approach to understand climate changes in the past and predict the weather in the future [9].

The effect of climate change on flood frequency was studied by using the outputs of General Atmospheric Circulation Model, $HADCM_3$ by A_2 scenario and its results showed that despite the average decrease of annual precipitation in studied basins, flood recurrence and frequency increase in most periods [10].

There are many models to analyze climate change, and currently, one of the most common and most reliable tools used to investigate and evaluate climate change for predicting the future decades is the General Circulation Model (GCM); its outputs have been downscaled by using statistical methods and are somehow close to real data. One of these models is LARS-WG that uses daily climatic parameters in a station such as precipitation, number of sunny hours, and minimum and maximum temperature to simulate the data for the future by utilizing available time series.

The fact is that the global temperature increase has a considerable effect on the climatic phenomena, especially on precipitation patterns [11].

II. Semnan Climatic Conditions

Semnan province's atmospheric conditions show diversity in the climate. This climate diversity reveals in two types:

Extreme semi-desert climate that is dedicated to plains, salt desert and parts of northern and central plateau of Iran and has covered portions of Semnan Province including Garmsar and Ben Kouh. In these regions, the amount of precipitation and rainfall is low and precipitation usually takes place in early spring and summer in some years.

Mild semi-desert climate has covered some portions of Khorasan, Semnan, Shahrood and Damghan, in addition to some parts of Iran. In these regions, precipitation usually takes place in fall and spring; however, most of precipitation occurs in winter. Semnan province is affected by warm and dry air streams of desert plains. It should be mentioned that factors such as distance from the sea, stretches and direction of the mountains, an area's elevation and winds are also effective in its climate and weather.

III. Three Types of Climate Specified in Semnan

The northern part of Semnan including Shahrood, Damghan, Mehdi Shar and Shahmirzad has dry and wet weather in winter and temperate weather in summer. The southern part including Garmsar and south of Semnan city has desert climate and relatively warm and dry weather in summer and cold weather in winter.

The northeast part of Semnan province consisted of Miami and Hossein Abad Kalpoush has temperate and humid weather in summer and cold weather in winter.

The average temperature range of Semnan city is 8.17°C, while it is 1.14°C for Shahrood and 5.17°C for Garmsar city. According to the figures, the coldest city among the four cities in this study is the province is Shahrood. Accordingly, Damghan is the hottest city, followed by Semnan and Garmsar. The average absolute maximum temperature recorded in July and August, which are the hottest months of the year, and January and February, which are the coldest months of the year, are 25°C and 11°C, respectively. In addition, the difference of average absolute maximum temperature between the coldest and hottest months is 31°C.

The atmospheric precipitation in Semnan province is very low and it is often as rain. Accordingly, the amount reaches to an average of 145 mm per year. According to the fact that the extent of relative humidity is directly connected with precipitation, it increases from west to east and south to north of the province so that percent of relative humidity is 49 in Shahrood and it is 41 in Garmsar.

Shahrood is among the cities of the province with the highest level of annual precipitation (1/161 mm) and on the contrary, Damghan is among the cities with the lowest level of precipitation (2/120 mm).

Diversity of surface roughness and adjacency of desert and mountains in the range of Semnan province (in addition to local winds) resulted in creation of westerly desert and winds.

TABLE I
LOCATION AND DURATION OF THE STUDIED STATIONS' STATISTICS

STATION	**period**	**LAT**	**LON**	**ELE**
Semnan	1964-2008	35.50	52.40	1130.8
Shahrood	1962-2008	39	54	1349
Garmsar	1986-2008	35	52	825

Fig. 1 Geographical position of Semnan province

IV. Data and Methodology

There are several models in climate change analysis which General Circulation Models (GCM) is one of the most common and trusted methods in order to study climate change and its evaluation to predict future decades. The obtained results are downscaled using statistical software and make it close to real obtained data as much as possible. LARS-WG is among those models in which climate parameters such as precipitation, radiation, and minimum and maximum temperature in three stations are used daily in order to simulate data for future use [11]. According to the fact that rise in temperature has a significant impact on climate phenomenon such as precipitation pattern, the present research is going to predict climate parameters in climate change condition and compare the obtained data in the context of studying the process of climate change.

In the present research, the daily climate parameters of stations in Semnan such as precipitation, radiation, and minimum and maximum temperature were obtained for all stations which had data for at least 20 years. In this regard, only three stations of Garmsar, Shahrood and Semnan had long time data (1962-2008). According to the normality of the data for the selected stations, t-test at 0.05 level indicated that there is not a significant difference between the averages of the modeled values and the observed data of climate parameters.

LARS-WG model was used in order to study climate effects. In addition, a baseline scenario was used for the statistical period from 1961-2008 in order to check the validity of the model and for calibration; afterwards, the model was implemented. Eventually, the model was implemented in order to predict the climate parameters for the years of 2010 to 2030. Using LARS-WG model, the daily values of minimum and maximum temperature, precipitation and radiation of the selected stations were calculated and the effects of climate change were specified based on A_2 scenario. In the following, in order to evaluate the ability of the model to simulate the observed data modeling data, the bias calculation and absolute error between the observed data and the model were investigated. The values of bias and absolute error are obtained using the formula:

$$BIAS = \frac{1}{n} \varepsilon_{i=1}^{n} (S_i - O_i) \quad (1)$$

$$MAE = \frac{1}{n} \varepsilon_{i=1}^{n} (S_i - O_i) \quad (2)$$

where S_i is the modeled values, O_i are the observed data and i is the value for months of year and its parameters consisted of minimum and maximum temperature, precipitation and radiation.

TABLE II
AVERAGE BIAS AND ABSOLUTE ERROR OF CLIMATE PARAMETERS FOR STATIONS IN SEMNAN PROVINCE CALCULATED BY LARS-WG DURING THE STUDIED DURATION

STATION	PERCIPITATION		RADIATION		MIN TEMP		MAX TEMP	
	Bias	**MAE**	**Bias**	**MAE**	**Bias**	**MAE**	**Bias**	**MAE**
GARMSAR	1.5	2.8	0	0.1	0	0.18	-0.1	0.16
SEMNAN	3.6	2.8	0	0.1	0.04	0.18	-0.12	0.16
SHAHROD	0.46	2.8	0.02	0.1	0.07	0.1	-0.14	0.16

V. RESULTS AND DISCUSSION

Using implementation of the model during the years of 2010-2030 (1389-1409 Hijri), the monthly values of the climate parameters for the selected cities of Semnan province were evaluated and the changes in the stations compared with the existing conditions were compared. The difference between the predicted values and observed values of the parameters of minimum and maximum temperature, precipitation and radiation are presented in Tables III-V.

According to Table III, the maximum difference between the average minimum temperatures will be at Garmsar station in November 2030 (about 1.4°) and the maximum temperature difference compared with the observed data will be in the fall season.

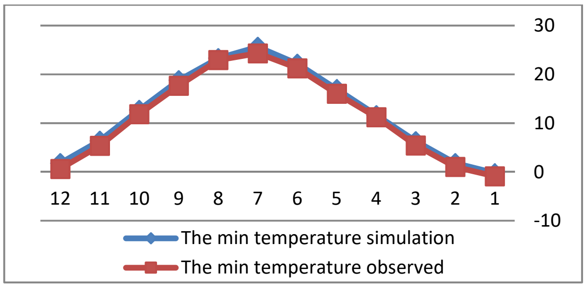

Fig. 2 Comparison of Minimum Temperature Simulation Data with Observational Data Garmsar Station during the years 2010 to 2030, on the A_2 Scenario

Therefore, according to Tables III and IV (long-time prediction presented for the three stations) there will be an increase in the mean monthly temperature. During the period 2010-2030, there will be an increase of 1.1°C in the minimum temperature and 2.7°C in the maximum temperature, and this shows that there will be more increase in temperature in summer and fall (according to $HADCM_3$ model) compared with spring and winter.

In addition, according to Table V, only the station in Semnan predicted 12.1% increase in precipitation based on A_2 scenario among the selected stations in which the maximum precipitation will be for April and November.

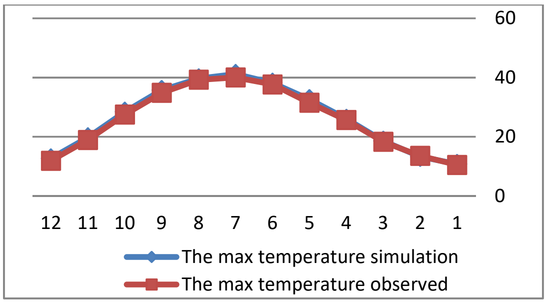

Fig. 3 Comparison of Maximum Temperature Simulation Data with Observational Data Garmsar Station during the years 2010 to 2030, on the A_2 Scenario

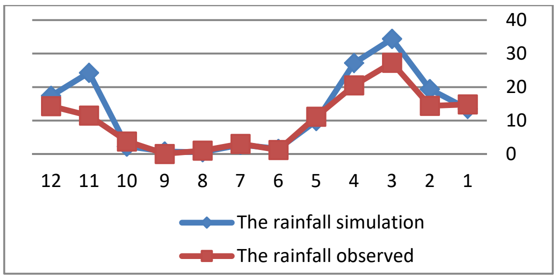

Fig. 4 comparison of rainfall simulation data with observational data Garmsar station during the years 2010 to 2030, based on the A_2 Scenario

TABLE III
DIFFERENCE BETWEEN AVERAGE MINIMUM TEMPERATURES OF THE MODEL AND OBSERVED DATA BASED ON THE RELATED MODEL DURING 2010-2030

MONTH	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC	
DECADE	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
GARMSAR	0.6	0.3	0.8	0.6	0.9	0.8	0.4	0.5	1	1	0.9	0.9	1.3	1.2	0.4	0.6	1.1	1	0.9	1.3	1	1.4	1.2	1
SEMNAN	0.3	0	0.7	0.5	0.4	0.3	-0	-0	-0	-0	-0	2.5	0.1	-0	-1	-1	-1	-1	-1	-0	-0	-0	0.4	0.1
SHAHROOD	2.3	2	2.7	2.7	0.5	1	0.7	0.2	0.7	0.7	0.3	0.7	1	0.9	1	1	0.8	1.2	1.4	1	1.1	1.2	1.3	0.8

TABLE IV
DIFFERENCE BETWEEN AVERAGE MAXIMUM TEMPERATURES OF THE MODEL AND OBSERVED DATA BASED ON THE RELATED MODEL DURING 2010-2030

MONTH	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC	
DECADE	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
GARMSAR	0.3	0.6	-0	-0	0.3	1	0.4	0.7	1.2	1.3	0.5	0.7	1.1	1	0.4	0.3	0.9	1	0.9	1.4	0.8	0.5	0.8	1.1
SEMNAN	2.6	2.8	2.3	2.3	1.9	2.5	2	2.3	3.1	3.4	3.1	5.5	3.4	3.3	2.8	2.7	3	3.1	3	3.5	2.4	2	2.1	1.2
SHAHROOD	4.2	4.5	4	3.8	0.5	0.8	0.8	1.4	0.8	0.9	0.1	1	1.1	1	1.1	1	0.6	0.9	1.6	1.8	0.7	0.7	0.7	0.7

TABLE V
DIFFERENCE BETWEEN PRECIPITATION OF THE MODEL AND OBSERVED DATA BASED ON THE RELATED MODEL DURING 2010-2030

MONTH	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC	
DECADE	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
GARMSAR	-1	6.6	5	-1	7.1	-2	6.6	7.4	-1	-1	0.4	0.4	-0	-2	-0	0.6	0.7	0.2	-2	1.4	13	10	3.1	8.8
SEMNAN	-6.8	1.1	0.2	-6.2	8.6	0.0	10.0	13.5	-3.4	-2.6	-2.3	-3.2	-0.3	-2.3	-1.8	-.8	-0.6	-1.0	-3.9	-1.0	15	12.4	-1.9	1.7
SHAHROOD	-6.2	0.16	-1.8	-5.5	12.4	14.6	5.7	20.8	3.8	1.2	-1.5	-0.2	3	5.2	2.2	1.5	4.6	-1.1	1.8	-3.8	-0.4	2.6	6.4	-7.8

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