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Investigating Climate Change Trend Based on Data Simulation and IPCC Scenario during 2010-2030 AD: Case Study of Fars Province

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***Abstract*—**The development of industrial activities, increase in fossil fuel consumption, vehicles, destruction of forests and grasslands, changes in land use, and population growth have caused to increase the amount of greenhouse gases especially CO_2 in the atmosphere in recent decades. This has led to global warming and climate change. In the present paper, we have investigated the trend of climate change according to the data simulation during the time interval of 2010-2030 in the Fars province. In this research, the daily climatic parameters such as maximum and minimum temperature, precipitation and number of sunny hours during the 1977-2008 time interval for synoptic stations of Shiraz and Abadeh and during 1995-2008 for Lar stations and also the output of $HADCM_3$ model in 2010-2030 time interval have been used based on the A_2 propagation scenario. The results of the model show that the average temperature will increase by about 1 degree centigrade and the amount of precipitation will increase by 23.9% compared to the observational data. In conclusion, according to the temperature increase in this province, the amount of precipitation in the form of snow will be reduced and precipitations often will occur in the form of rain. This 1-degree centigrade increase during the season will reduce production by 6 to 10% because of shortening the growing period of wheat.

***Keywords*—**Climate change, Lars.WG, $HADCM_3$ model, Fars province, climatic parameters, A_2 scenario.

I. Introduction

CLIMATE changes are considered to be one of the biggest environmental threats for the world in 21th century and it is estimated that extreme precipitation variations will have more negative effects on human, society and natural environment than average weather conditions variations [1].

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 [2]. According to the studies done about climate change in Southern Korea (2010-2039) by the use of LARS-WG model, it is generally verified that the amount of precipitation will increase in the future but in the final years of 2010s and it will face a relative loss of precipitation. Also, the mean temperature will increase in future decades with respect to the previous period [3]. Efficiency of the two models, LARS-WG and WGEN were investigated in 18 synoptic stations of America, Europe, and Asia and the results showed that the LARS-WG has a better compatibility with monitoring data compared to WGEN model [4]. 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 [5]. Climate change will have positive effects on agricultural productions in some regions of the world, especially in the areas that are located in northern latitudes higher than 55 degrees, but its negative effects will be very intensive in warm and dry regions. Temperature increase and precipitation decrease will be more intensive in developing countries and besides the frequency and severity of rare climate phenomena (drought, heat, cold and flood) will be intensified [6]. A lot of researchers emphasize that because the areas located in the middle latitudes (15 to 40 northern) will face significant increase of temperature and considerable reduction of precipitation based on future climate forecasts, drought indices are the most appropriate criteria to evaluate the regional effects of climate changes in these areas. Based on available evidences, drought expand and extent in tropics and subtropics will be of the characteristics of the future climate [7]. There are many models to analyze the climate change and currently one of the most common and most reliable tools that is used to investigate and evaluate the climate change for predicting the future decades, is the General Circulation Model (GCM) that its outputs have been downscaled by using statistical methods and is 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, minimum temperature and maximum temperature to simulate the data for the future by utilizing available time series.

Regarding the fact that the world temperature increase has a lot of effects on climatic phenomena, especially on precipitation pattern [8], the goal of this research is to predict weather parameters in climate changing conditions and compare those data to investigate the trend of climate change.

II. Geographical location of Fars province

Fars province is about 7.6% of the total area of Islamic Republic of Iran. It is located in the south of central Iran

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between 27˚ 2″ and 31˚ 42″ northern latitudes and 50˚ 42″ and 55˚ 36″ eastern longitudes of the Greenwich Mean Time.

TABLE I
LOCATION AND RECORD LENGTH OF THE STUDIED STATIONS

Station	Record length	Latitude	Longitude	Height
Shiraz	1977-2008	52	29	1484
Abadeh	1977-2008	52	31	2030
Lar	1995-2008	54	27	792

Fig. 1 Under study area

III. WEATHER CONDITIONS IN FARS PROVINCE

A. Temperature and Rainfall

Under the influence of topographic features, there are three weather conditions in Fars province:

- North, northwest and west mountainous area has moderately cold winter and there is considerable vegetation. About 400 to 600 mm/year rainfall has been reported in this area.
- The central area has a relatively temperate climate with rainfall in winter and it has a hot and dry weather in summer. This area has a totally different climate compared to north and northwest due to relatively high level of rainfall. Furtheremore, 200 to 400 mm/year rainfall has been reported in this area. Cities of Shiraz, Kazeroun, Fasa and Firouz Abad are located in this area.
- The area of south and southeast has a low level of rainfall in winter compared to spring and autumn due to the altitude reduction, geographic width and the way of distribution of mountains. This area has a moderate weather in winter and a very hot weather in summer so that the rainfall level is 100 to 200 mm/year. Lar, Ouz and Khenj are located in this area of Fars province.

According to Shiraz synoptic station in 2012, the average weather temperature in this city was 16.85 °C. Moreover, the absolute maximum and minimum temperature were 4.74 and 2.92 °C, respectively. Accordingly, the average monthly rainfall was 48.45 mm, the maximum amount of rainfall was equal to 184.2 mm in December, and the minimum amount of rainfall was equal to 0 in July, September and October. The maximum and minimum average relative humidity in the area were 84.5 and 12.5%, relatively. In addition, the number of frost days during the year was reported to be 34.

IV. METHODOLOGY

In this research, monthly precipitation amounts, minimum temperature, maximum temperature and number of sunny hours were calculated for all of the stations located in Fars province since 1971 to 2009 AD by using LARS.WG method and downscaling General Atmospheric Circulation Model ($HADCM_3$) data and based on daily information provided by the database of National Meteorological Organization [9]. But, we just refer to three stations –Shiraz, Abadeh, and Lar- in this paper. This model has been implemented to predict long-term climatic parameters between 2010 and 2030 AD. First of all, the intended parameters for selected stations were calculated by using Lars-WG program and then A_2 scenario has ALSO been simulated based on HADCM3 model [10]. Next, bias and error between monitored data and model has been utilized to evaluate the reliability of the data and for the general strength of the model in simulating observational data (Table II). The bias and absolute error will be calculated by using the following equations:

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

$$\text{MAE} = \frac{1}{n}\varepsilon_{i=1}^{n}|S_i - O_i|$$

O_i represents the observational data and S_i is expressing modeled data which contain the maximum and minimum temperature, precipitation, and number of sunny hours. The index *i* in this formula refers to the months of the year.

TABLE II
MEAN BIAS AND ABSOLUTE ERROR OF CLIMATIC PARAMETERS MODELING IN STUDIED STATIONS OF FARS PROVINCE

Station	Precipitation		Number of sunny hours		Minimum temperature		Maximum temperature	
	Bias	MAE	Bias	MAE	Bias	MAE	Bias	MAE
Shiraz	0.72	2.8	0	0.11	0.09	0.18	0.03	0.16
Abadeh	2.03	2.09	0.06	0.12	0.09	0.18	-0.03	0.21
Lar	4.81	5.24	-0.06	0.11	0.07	0.17	-0.11	0.17

V. CONCLUSION

Monthly climatic parameters for the years between 2010 and 2030 AD were estimated for selected stations of Fars province by implementing the related model and the changes occurred in stations were compared with the current situations. The difference between predicted values and observational data of maximum and minimum temperature and precipitation are presented for 2020 and 2030 decades in Tables III-V.

A. Investigating the Trend of Climate Change in 2010-2030 Time Intervals for Fars Province

Temperature and precipitation has been calculated in the stations of Fars province during the intended time interval according to the $HADCM_3$ model and based on the A_2 propagation scenario. The results show that:

1. Minimum interval in studied stations during simulated years will have the most variation with observational data in spring and fall. The largest difference in minimum temperature for Shiraz station will be about 1.19 degrees in October in 2010 decade and the minimum difference will be about -0.09 degrees centigrade in February.
2. Difference in the maximum temperature for the aforementioned station will be about 1.5 degrees as the most in 2020 decade in March and about -2.5 degrees as the least in February. In general, the calculated temperature in the studied stations during the predicted time interval will be about 1 degree centigrade higher than the observational temperature.
3. The amount of precipitation computed based on this model in the studied areas of the province will be about 23.9% higher than its observational amount in the intended time interval in a way that it increases 29.4% in spring, 20.5% in fall and 39% in winter.

But because of 1-degree centigrade increase in temperature in the province, the precipitation patterns will change and will mainly be in the form of rain. The change in precipitation patterns and the heterogeneous distribution of precipitation will be on the most sensible consequents of climate change phenomenon in our country Iran.

TABLE III
THE DIFFERENCE BETWEEN MEAN MINIMUM TEMPERATURE OF THE MODELED DATA AND OBSERVATIONAL DATA BASED ON THE DESIRED MODEL DURING 2010-2030 AD

Month	**Jan**		**Feb**		**Mar**		**Apr**		**May**		**Jun**	
Station	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
Shiraz	0.89	0.59	0.09	0.81	1.02	2.58	1.3	1	1.11	1.21	0.8	0.6
Abadeh	0.61	0.91	1.12	0.52	0.77	1.17	0.81	0.91	1.02	1.02	0.83	0.63
Lar	-7.6	-7.3	-7.4	-8	-7.2	-6.8	-7.1	-7	-8.1	-8	-7.5	-7.7
Month	**Jul**		**Aug**		**Sep**		**Oct**		**Nov**		**Dec**	
Station	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
Shiraz	0.89	1.09	0.88	0.88	1.03	0.83	1.19	0.89	1.24	1.54	0.6	0.6
Abadeh	2.2	2.1	1.09	1.09	0.87	0.87	1.3	1.4	0.6	1.1	1.12	0.72
Lar	-7.4	-7.4	-8.9	-8.9	-9	-9	-8	-7.9	-7.6	-7.1	-6.5	-6.9

TABLE IV
THE DIFFERENCE BETWEEN MEAN MAXIMUM TEMPERATURE OF THE MODELED DATA AND OBSERVATIONAL DATA BASED ON THE DESIRED MODEL DURING 2010-2030 AD

Month	**Jan**		**Feb**		**Mar**		**Apr**		**May**		**Jun**	
Station	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
Shiraz	0.51	1.01	2.5	0.8	1.5	-4.6	0.4	0.7	1.39	1.29	0.55	0.55
Abadeh	-0.3	0.58	0.5	0.3	2.65	2.35	0.95	0.45	1.42	1.22	0.61	0.51
Lar	-8.3	-9.2	9.2	-9	-7.1	-6.8	-9.8	-9.3	-10	-9.8	-9.1	-9
Month	**Jul**		**Aug**		**Sep**		**Oct**		**Nov**		**Dec**	
Station	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
Shiraz	1.02	1.22	0.85	0.85	0.98	0.78	1	0.8	1.15	0.75	0.79	0.79
Abadeh	2.52	2.62	1.8	1.7	0.91	0.91	1.74	1.64	1	1	1.47	1.67
Lar	-7	-7.1	-7.3	-7.2	-8.3	-8.3	-8.5	-8.4	-9.2	-9.2	-7.7	-7.9

TABLE V
THE DIFFERENCE BETWEEN PRECIPITATION FROM THE MODELED DATA AND OBSERVATIONAL DATA BASED ON THE DESIRED MODEL DURING 2010-2030 AD

Month	**Jan**		**Feb**		**Mar**		**Apr**		**May**		**Jun**	
Station	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
Shiraz	44.7	18.4	20.7	4.5	15.1	5.1	28.8	-1.3	3.1	0.8	0.05	0.2
Abadeh	13.7	12.8	8.7	-1	9.9	16.9	4.8	8.08	3.4	0.8	-0.2	4.48
Lar	-27	6.47	20.5	11.5	-9.4	-2	-0.7	14.7	2.1	1.4	3.9	3.3
Month	**Jul**		**Aug**		**Sep**		**Oct**		**Nov**		**Dec**	
Station	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
Shiraz	0.6	2.1	1.3	-0.1	0.4	0.1	0.4	3.5	-4.5	32.4	-5.6	5.7
Abadeh	-0	0.67	0.3	-0.2	0.2	0	0.9	2.53	7.2	-0.4	2.6	12.9
Lar	6.7	-3	3.6	5.75	2.9	1.5	3.2	-3.4	1.56	4.6	24.9	-16

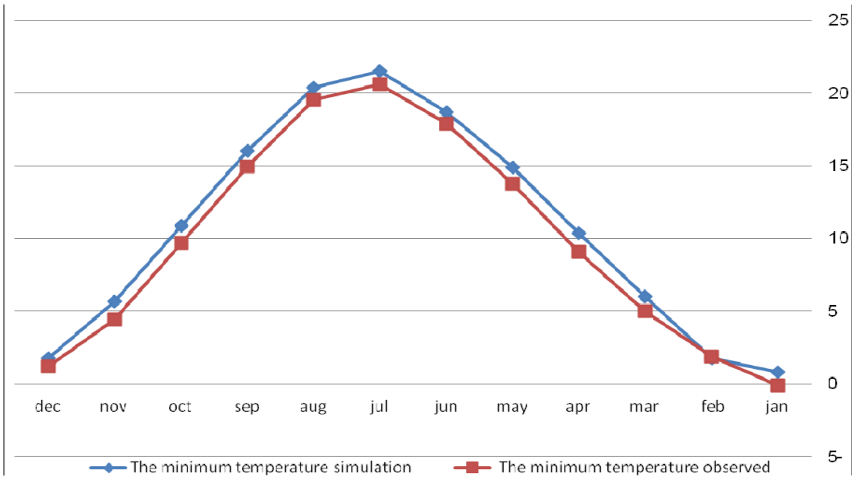

Fig. 2 Comparison of Minimum Temperature Simulation Data with Observational Data Shiraz Station during the years 2010 to 2020 Ad, on the A_2 Scenario

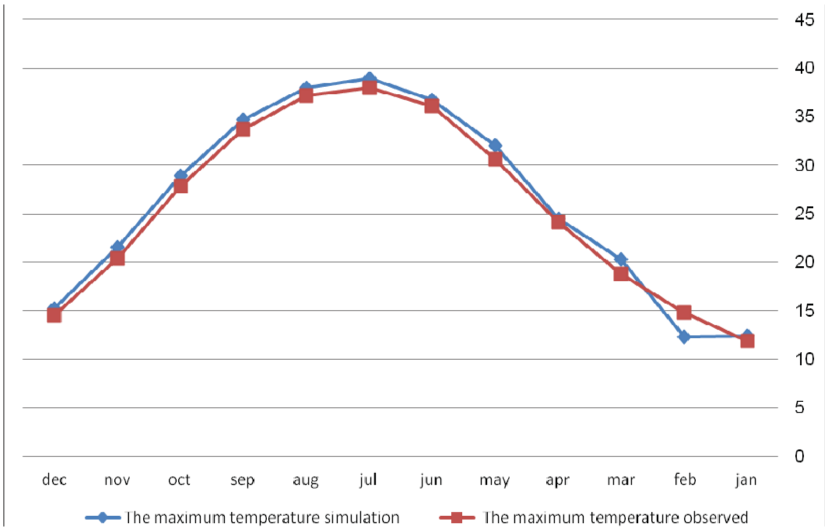

Fig. 3 Comparison of Maximum Temperature Simulation Data with Observational Data Shiraz Station during the years 2010 to 2020 Ad, on the A_2 Scenario

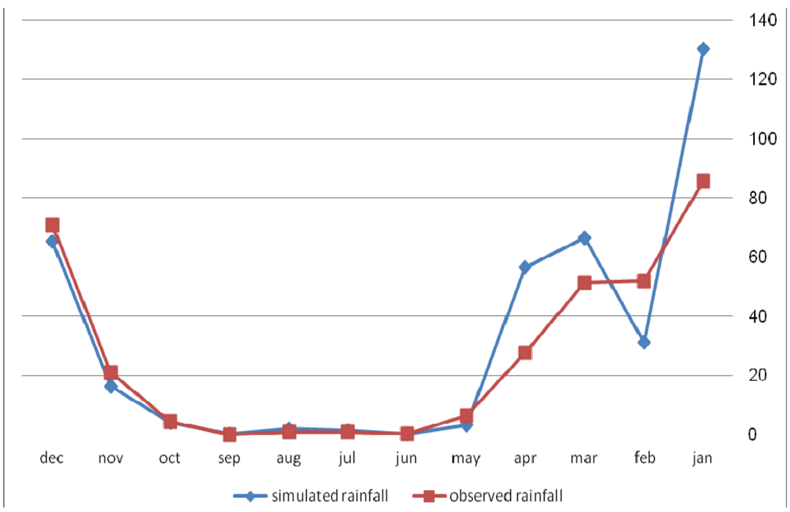

Fig. 4 Comparison of rainfall simulation data with observational data Shiraz station during the years 2010 to 2020 Ad, based on the scenario A2

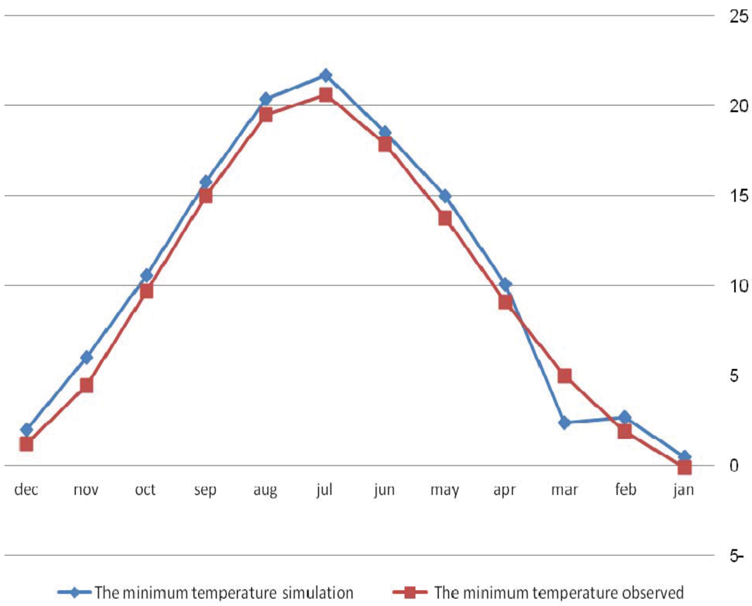

Fig. 5 Comparison of Minimum Temperature Simulation Data with Observational Data Shiraz Station during the years 2020 to 2030 Ad, on the A_2 Scenario

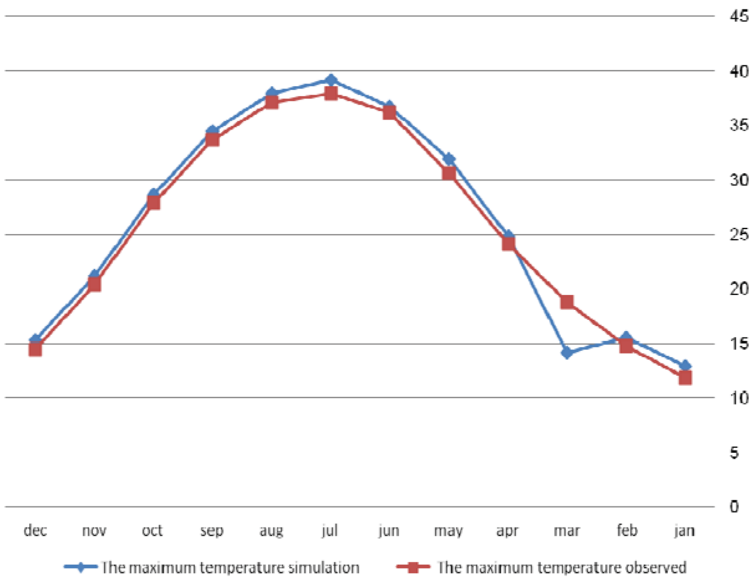

Fig. 6 Comparison of Maximum Temperature Simulation Data with Observational Data Shiraz Station during the years 2020 to 2030 Ad, on the A_2 Scenario

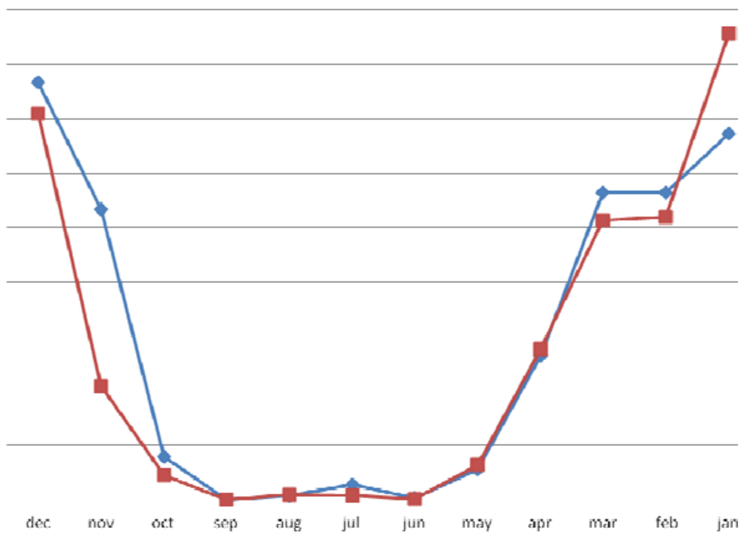

Fig. 7 Comparison of rainfall simulation data with observational data Shiraz station during the years 2010 to 2020 Ad, based on the scenario A2

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