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Climate Change Assessment over Zagros During 2010-2039 by Using Statistical Downscaling of ECHO-G Model

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Abstract: Because of low special resolution of General Circulation models, they can not predict weather and climate accurately. In this regards weather generator technique have been developed by climatologists to downscale GCM outputs into station scale. In this research, girded meteorological outputs of ECHO-G model including precipitation, maximum temperature, minimum temperature and radiation have been downscaled over 18 synoptic stations of Zagros during 2010-2039 with A1 scenario. Results show that the mean annual precipitation will be decreased by 2%, increasing of mean annual temperature by 0.4°C during period of 2010-2039. Maximum increase predicted to occur over Fars, Esfahan provinces. Also thresholds of heavy and extreme rainfall will be increased by 3 and 19%, respectively. In this regards in the future period, the rainfalls will be heavy and flash-flooded and there is a significant decrease in the amount of snow falls.

Key words: Climate change, general circulation model, downscaling, extreme events, Zagros, Iran

INTRODUCTION

Climate change is of great significance since it enjoys different scientific and operational detentions and environmental, economical and social effects. Another reason is that human systems dependant on climatical elements like agriculture, industry and so on are all designed based on fixed and constant climate operating based on the same reason.

In order to evaluate the climate change in future there is required to induce climatical scenarios at the present time, the most valid device for having climatical scenarios are three dimentional paired ocean atmospheric general circulation models. These models are based on the presented physical rules explained with mathematical relationships. These relationships are solved in a three dimentional network in the earth globe surface. One of the main inlets in these models is the distribution amount of gas in the earth atmosphere which is introduced under different distribution scenarios in the CSGS model. The involved scenarios are B2, B1, A1, A2 which are all developed by the international association of climate change and show the climate status in future decades evaluating different hypothesis.

Climatical models try to predict climate and its related changes considering the different effective elements affecting the climate and the mathematical formulation. Diagnosis of physical solutions and their correct formulation in addition to having appropriate observational data is considered one of the most effective yardsticks in climatical modeling. There can devide these models into international and local climatical models.

In studies evaluating climate change effects in local levels, one of the major problems in using present models is the extensive area of prediction variables in these models (checking areas about 5000 km^2) which considering topographical and climatical changes in this area, researchers can not draw on induced results in station scale. As a result, there are different methods in order to produce climatical scenarios in local scale which are called down-scaling. Down-scaling methods divide into two major parts, statistical method and dynamic method using different down-scaling methods there can review climatical changes resulting from gas increase in future.

Comparing statistical down-scaling method with dynamic ones especially when low cost and fast evaluation of effective factors on climate changes are required is of great advantage. Among studies done on climatical modeling of different world areas using statistical modeling, researchers can refer the study of Thompson (Babaeian *et al*., 2004; Dubrovsky, 1996) about 30 years modeling climate of air stations in Newzeland. Johnson *et al*. (1996) and Dubrovsky (1996) have studied two different models producing air data named USCLIMAMATE, CLIGEN.

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In a research the hydrology effects of climatical change was studied by Elshamy *et al*. (2006) using GCM models and a small downscaling analog model.

In this study it was studied that how monthly data can be changed to daily one by airiology generator techniques. Harmel *et al*. (2002) introduced SDSM model for downscaling temperature and rainfall information using statistical methods. CLIMGEN is one of the spontaneous generators of climate data of Richardson kind which estimates time series related to daily rainfall, temperature, dew point, wind and sunshine for specific location (Johnson *et al*., 1996).

Harmel *et al*. (2002) and Field *et al*. (2001) in the united states agricultural investigation institute modeled the maximum and minimum temperatures of airology stations in the united states using statistical models. Bureau of Meteorology (1991) presented a method for application of climate change scenarios using WGEN model which is one of the gerative airology models of this kind. This model could be used for producing minimum and maximum daily temperature, rainfall and daily sunshine data IARC (1988) studied. The potential of CLIMGEN model for assimilating ariology parameters in south Ontario station in Canada.

In Martin Dubrovsky's study in Czec Republic the model MET and Roll was evaluated. This model makes the necessary model for maximum and minimum temperature, sunshine and rainfall data on one air station. CLIMGEN is one of the spontaneous generators of climate data of Richardson kind which estimates time series related to daily rainfall, temperature, wind and sunshine for specific location. Field *et al*. (2001), Bureau of Meteorology (1991) and IARC (1988) in a research studied the assimilation of the data using LARS-WG model in England. In a research, (Johnson *et al*., 1996) evaluated the climatical changes in south Korea using LARS-WG model in 2010-2039 period.

In the present study scenario A1 data of model ECHO-G have been used in order to evaluate Zagros climatical changes employing downscaling statistical-exponential method and LARS-WG model.

MATERIALS AND METHODS

Zagros mountains located in west of Iran plateau is one of the vast mountains which continues from around Marivan to Hormoz in its west north and east south wing. Zagros area is one of the most rainy areas of the country in spite of the fact that some ports of this region in terms of rainfall height are placed after west bank of Caspian sea and equal to south banks. Great height and the general inclination of the mountains which are exposed to west and Mediterranean diagonal air masses causes' large amount of rain and snow fall in these. In the same way, these high lands are considered as the source of major rivers like Karoon, Dez and Karkhe. The east domain of the mountain complex, considering its high distance from humidity and rainfall source and locating in a wind shelter area, enjoys less rain and snowfall comparing west domains. With the exception of Zayande rood there is no other important river having its source here. Zagros area climate is moderate, humid with intense seasonal rainfall. Humid flows and sicelons leave their most humidity in the west domains of Zagros. These sicelons from the west originating from Mediterranean (Mediterranean sicelons) and from the south west originating from Sodan (Sodanian sicelons) influence the whole area.

Mediterranean sicelons due to passing the lands east of Mediterranean sea, lose most of their humidity before reaching Iran because they face both cold and hot weather. But Sodanian sicelons although, they have a longer path in front, they absorb the humidity all on their way from Red sea and then Persian gulf an in addition to this warmer weather causes that humidity capacity of the weather increase especially in upper layer. Thus being close to humidity feeding source and the warm weather as two major rainfall systems play a major role in rainfall increase in south areas of the region. The humid weather of west rainfall systems and the western south ones after arriving at the western domains would produce rainfall because of getting gold and piled up due to dynamic climb. For the same reason the rainfall amount would decrease the rainfall amount upward to highlands.

One of the most famous generative models of accidental data on weather condition is LARS-WG model which is employed for producing, daily rainfall, sunshine, maximum and minimum daily temperature in a station under climatical condition of present and future.

Weather parameters (Weather generator) are models which using statistical methods downscales the output of numerical general circulation model of the atmosphere which very much resembles with the real amount in station scale the first version of LARS-WG was introduced in Budapest during the year 1990 as a device for statistical down scaling in Hungary. The basis of this model and its theoretical framework is presented in Rasco's study. This models is used for modeling complex statistical distributions of weather variables. The basis of this modeling is semi-experimental for dry or wet priods, daily rainfall and sun shining series.

In semi-experimental distribution the distance is equally divided among maximum and minimum monthly time series:

$$\text{EMP} = \{a_0, a_i, h_i,\ i = 0, 1, 2, ..., 10\}$$

In which EMP is a histogram with ten intervals of different rainfall intensities.

$$[a_{i-1}, a_i] \qquad a_{i-1} < a_i$$

Distances are ascending for length of the wet and dry days. In this model, sun shining is modeled independent of the heat temperature and there can use an alternatively. The rainfall amount in one wet day is yielded on the basis of the semi-experimental distribution of the given month and independent of wet series or amount of fall in the previous day. In this model, February series estimate the temperature and the minimum and maximum daily temperatures are modeled as accidental processors with the mean and daily standard diviation which is dependent on wet or dry status of the day. February series of the third degree is used for assimilation of mean and standard deviation for seasonal temperature. The remaining amounts is introduced by subtracting mean amounts from observed amounts. In a time correlation study, minimum and maximum data are employed. Producing data by LARS-WG model is done in three phases which are as follows: calibration, evaluation and establishing weather data.

In this model first the data on general circulation model of the atmosphere ECHO-G including rainfall ,minimum temperature, maximum temperature and sunshine are extracted in a daily manner and for each network in ECHO-G model a specific scenario for data production is devised.

In order to devise such a scenario, there is required to compare the network data of model ECHO-G in future priod with the data related to the basic priod. Here the basic period 1976-2005 and the future period is considered to be 2010-2039.

In addition to the devised scenario for each calculational network for applying LARS-WG model, indicating file for previous climate behavior of stations located inside the network is required. After that receiving the file of previous climate behavior of the station and the file of producing data scenario it computers the amounts of minimum and maximum daily temperature, rainfall and daily sunshine in future.

The operating model mechanism is in the way that first it perturbates all the monthly data using producing monthly data scenario which involves the basic climate behavior according to the following formula:

$$F_{fut} = F_{obs} + (F_{GCM}^{fut} - F_{GCM}^{base}) \quad (1)$$

In which $F^{fut}{}_{GCM}$, F_{obs}, F_{fut}, $F^{base}{}_{GCM}$ are indicating weather parameters on airiology stations, weather parameter observed in the same station, weather parameter predicated on network model in future period and weather parameter modeled on network model in previous, respectively. Then, keeping the mean ther can yield the standard diviation by this formula:

$$STD_{fut} = \frac{STD_{base}^{OBS}}{STD_{base}^{GCM}} \times STD_{fut}^{GCM} \quad (2)$$

in which STD is the standard diviation, weather parameter under process. This research is done for checking the climatical change in Zagros area on is synoptic station located in this area which enjoys perfect statistics in the basic period 1976-2005. The name and geogerphical specification of the station is shown in Table 1.

In this study, stations having considerable deficiencies are all omitted considering the imbalance in length of statistical period in the given stations, period 1976-2005 is considered as the basic period. In general, the capacity of the generative model of climate data has direct effects on the climate change in the area being studied. So, first the capacity of this model was evaluated using 30 year observed data in is synoptic stations in Zagros area. This task was done by comparing the statistical period data with the data produced by the model using statistical methods, map and diagram. In order to do this a basic mode scenario for statistical period 1976-2005 was devised and LARS-WG model for the given basic period was applied.

The observed and modeled data of four parameters, maximum and minimum temperature, rainfall and sunshine using student test were compared with each other. Doing the statistical analysis of the modeling results of 18 synoptic stations in Zagros area it was considered that between maximum and minimum temperatures of the model and the observed similar amounts there is a very good correspondence. Modeling the daily rainfall in all the stations were generally acceptable. But the daily rainfall standard diviation of the model in most of cases was less than the observed data.

In general, the result shows the LARS-WG capacity in modeling the basic period climate of the stations under study based on the basic mode scenario. In Fig. 1 for instance, comparing maximum and minimum temperature

Table 1: The geogerphical specification of the stations

Station	Longitude (e)	Latitude (n)	Elevation (m)
Abadan	48.25	30.37	6.6
Abadeh	52.67	31.18	2030.0
Arak	49.77	34.10	1708.0
Esfahan	51.67	32.62	1550.4
Ahvaz	48.67	31.33	22.5
Khoramabad	48.28	33.43	1147.8
Dezful	48.38	32.40	143.0
Saghez	46.27	36.25	1522.8
Sanandaj	47.00	35.33	1373.4
East of esfahan	51.87	32.67	1543.5
Sharekord	50.85	32.28	2048.9
Shiraz	52.60	29.53	1484.0
Fasa	53.68	28.97	1288.3
Kashan	51.45	33.98	982.3
Kermanshah	47.15	34.35	1318.6
Hamedan forodgah	48.53	34.87	1740.8
Hamedan nozhe	48.72	35.20	1679.7
Yazd	54.28	31.90	1237.2

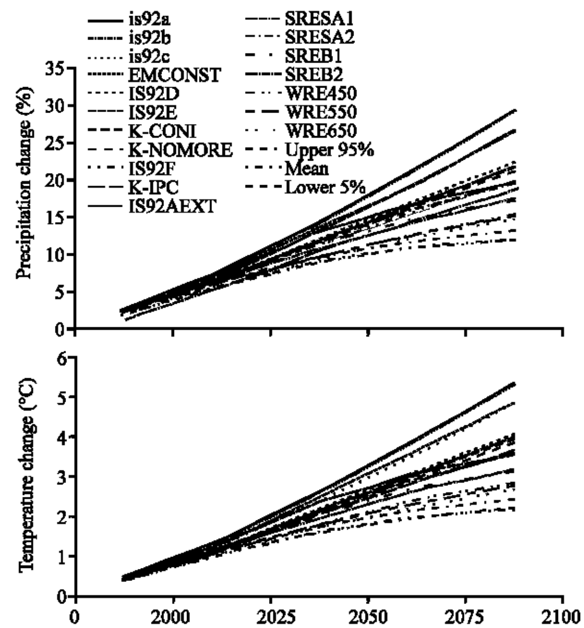

Fig. 1: Comparing maximum and minimum temperature amounts, rainfall and the sunshine

amounts, rainfall and the sunshine resulting from LARS- WG model with observed similar data is considered. After this, for evaluating Zagros climate change in 2010-2039 period, climate change scenario on six calculational network of ECHO-G model which include Zagros area in its network are devised based on two basic periods 1976-2005 and in future 2010-2039.

Then, the final climate behavior file of the basic period in all the stations would be perturbated by LARS-WG model and the minimum and maximum daily temperature data got produced. Using the output model, other climate variables including the number of hot days, ice days were also calculated and checked.

RESULTS AND DISCUSSION

In Table 2, the mean amounts of monthly rainfall and their standard diviation have been brought. It is considered that in some month, standard diviation in statistical period. In Fig. 2, the amount of annual rainfalls and without applying this ratio is demonstrated.

According to the above table the rainfall amounts in fall in all months and in winter in January and in spring in may and in summer in july have been decreased in spring and fall, rainfall of 2020 decade comparing with the normal amount would decrease 11 and 3% and rainfall amount in summer and winter would increase 16% comparing to statistical period.

In Fig. 3, the diagram of monthly rainfall mean for studied stations have been brought. As ther may observe the rainfall mean in this area except the month February

Table 2: Comparing the mean and rainfall standard diviation (mm) and in temperature in basic perio and 2020 decade in all studied stations

Rain	Jan.	Feb.	Mar.	Apr.	May	Jun.
Clima	50.8	39.8	52.8	31.0	16.3	1.6
SD	5.5	4.7	5.2	3.8	2.5	0.6
Future	47.1	47.7	53.8	32.1	13.1	2.1
SD	4.8	4.9	5.0	3.7	2.5	0.9
Rain	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Clima	1.1	0.8	0.3	13.2	31.7	52.3
SD	0.6	0.5	0.4	2.5	4.5	6.0
Future	1.0	0.8	0.7	10.0	27.5	49.0
SD	0.6	0.7	0.3	1.9	3.3	5.1

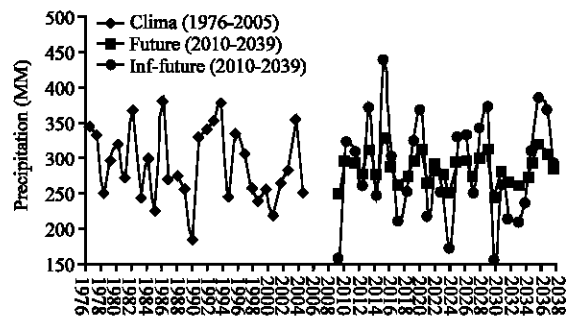

Fig. 2: The amount of annual rainfalls and without applying this ratio is demonstrated

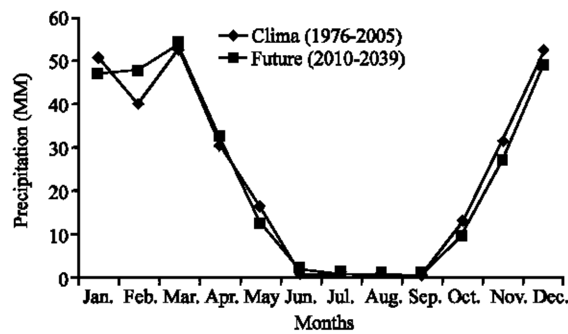

Fig. 3: The diagram of monthly rainfall mean for studied stations

March, April, June and September which comparing to normal amount has increased a little, in other month of the year would be less than normal amount. The most decrease comparing to normal amount is related to November which comparing to normal amount the rainfall has gone through 13% decrease. It can be shown in Fig. 2, standard diviation of rainfall amounts annually produced comparing to the standard diviation in the observed period have increased based on formula 2 in the similar period on general circulation model of the atmosphere.

In Fig. 4, the rainfall differences in 2020 decade comparing to the basic period (1976-2005) is observed. In this period except some provinces like fars, Boushehr, Chehar mahal Bakhtiari and Kohgilouye and Boyer ahmad

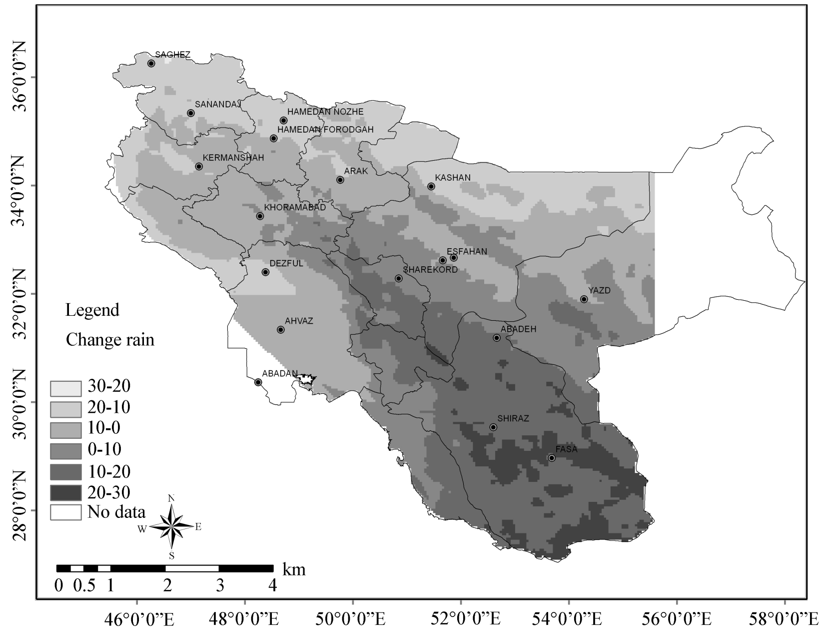

Fig. 4: The rainfall differences in 2020 decade comparing to the basic period (1976-2005)

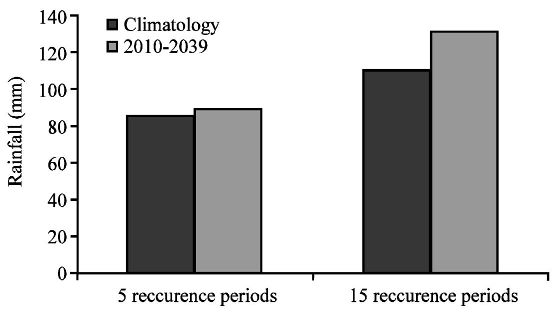

Fig. 5: The heavy rainfall in 2010-2039. (Daily thresholds with 5 and 15 reccurence periods in climatology (1976-2005) and (2020s)

and some parts of Isfehan, Yazd, Khoram abad, other provinces in 2020 decade would face rainfall decrease. The most rainfall decrease would be in Kordestan with 10-20% and the most increase would be in Fars with 12%. In general, armual rainfall in all the stations selected in Zagros area would go through 2% decrease comparing to the statistical period in 2020 decade.

Heavy rain falls: Heavy rain falls threshold which are defined as the rainfalls with 5 year return period are calculated in the basic period and 2010-2039 period. The same task has been done on very heavy rainfall (with 15 year return period).

It can be shown in Fig. 5, heavy rainfalls 3% increase from 86 mm in the basic period to 89 mm in the period 2010-2039. The very heavy rainfall threshold like heavy rainfall threshold have also gone through an increase and with 19% increase from 110 mm in basic period has reached 130/8 mm in 2020 decade.

Temperature mean: In Table 2, the mean and standard diviation amount for the temperature of the studied area in basic period and 2020 decade have been brought. Like rainfall and keeping the temperature maens, its standard diviation have increased comparing to the standard diviation of general circulation model amounts of the atmosphere in future in basic period. The results show that the temperature maen in the area in period 2010-2039 in the months April and July have decreased to normal amount and in other months of the year the temperature mean would increase. The most temperature mean increase is related to winter with 1.1°C and after this, researchers have fall season which its temperature mean comparing to the statistical period has increased with 0.7°C. In other words, temperature increase in the cold season of the year is more than other seasons.

Figure 6 shows monthly temperature means in Zagros area in 2020 decade and in the basic period. The temperature has increased in most months of the year comparing to the statistical period. The most temperature increase in January, February and December were 1/4, 1/2 and 1°C, respectively. Distribution of temperature mean changes in Zagros in future period (2010-2039) comparing to the basic period (1976-2005) has been shown in Fig. 7. It is considered that in future period (2010-2039) are among Zagros area provinces, the most temperature in crease in Fars, Cheharmahal Bakhtiari and Kohgilouye and Boyer Ahmad boushehr, west parts of Isfehan, Yazd, south part of Khoram Abad, eastern south of Khouzestan.

In addition to this among stations under study, the most temperature increase is related to Fasa stations and

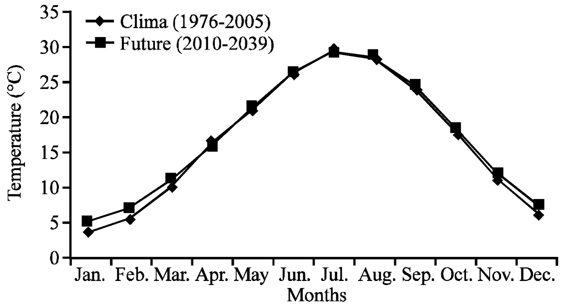

Fig. 6: The average temperature in 2010-2039

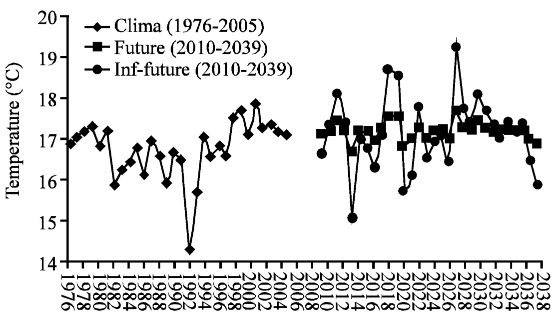

Fig. 7: The average temperature in Zagros untill to 2039

shiraz which are 1.1 and 1°C, respectively. It is considered that in future period (2010-2039) are among Zagros area provinces, the most temperature in crease in Fars, Cheharmahal Bakhtiari and Kohgilouye and Boyer Ahmad boushehr, west parts of Isfehan, Yazd, south part of Khoram Abad, eastern south of Khouzestan. In addition to this among stations under study, the most temperature increase is related to Fasa stations and Shiraz which are 1.1 and 1°C, respectively (Fig. 8).

Temperature mean in Ahwaz and Dezful stations would slightly increase comparing to statistical period. In general, temperature mean of the area in 2010-2039 period increases 0/4°C comparing to statistical period.

Hot and icy days: Based on the definition, a hot day in which the maximum temperature of the day exeeds 30°C. Using the results, the model for the number of hot days in 2010-2039 periods and the basic period in the country is extracted. Based on this, the mean number of hot days has ascending behavior in all month of increase is related to January, April, June and September. The most increase is related to October with 0.5 in a day. Icy day is a in which the minimum temperature is zero or less. Based on this definition, the number of icy days for two basic periods (1976-2005) and future (2010-2039) are extracted, the results show that in all months of the year the mean number of icy days would decrease comparing to the statistical period.

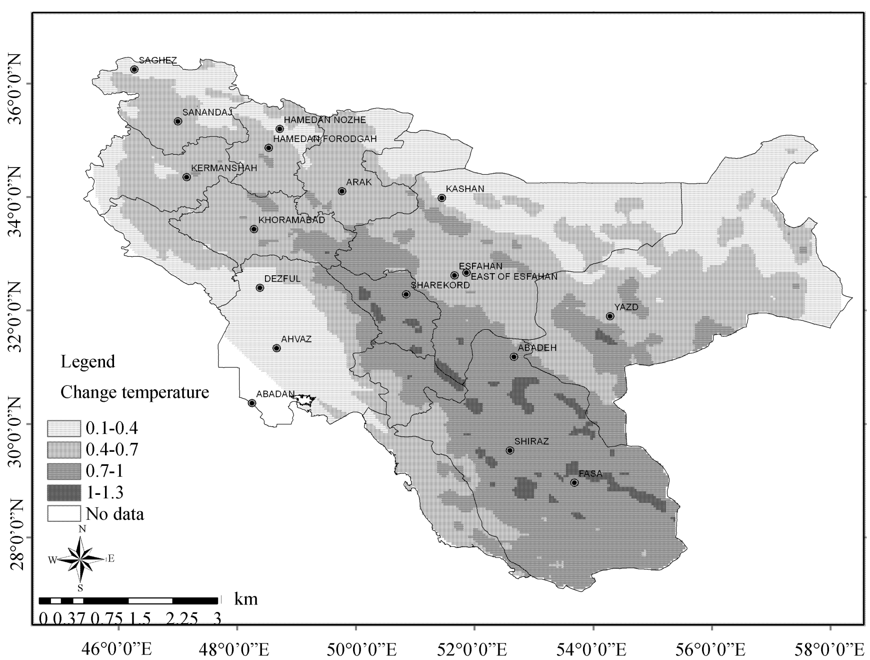

Fig. 8: Difference of annual temperature in Zagros untill to 2039

CONCLUSION

In this study, in order to evaluate Zagros climatical change in period 2010-2039, the output of general circulation model of the atmosphere ECHO-G with Al-default scenario are downscaled on is synoptic stations of the area. LARS-WG model was employed for downscaling. At first LARS-WG model capacity on is weather stations was checked. In order to do this, one basic mode scenario for basic period 1976-2005 was devised and the model was applied based on the mentioned scenario. Also, its capacity in preview climate assimilation was analyzed after the correction analysis was done, LARS-WG model was applied on all the stations under study in period (2010-2039) using devised scenarios for 15 calculation networks (in ECHO-G model, in Zagros area 15 causational networks are covered) and the most significant results are as follows: in the whole decrease in 2% comparing to the statistical period. The most decrease among the northern stations of the area under study was related to Sagez station in sanandaj.

The heavy rainfall threshold and the very heavy one in 2020 decade with 3 and 19% increase would reach to 89 and 130/8 mm, respectively comparing to the normal amounts considering the rainfall decrease in the area and increase in threshold amount of rainfalls it seems that in future decades researchers will face with more floods. The temperature means in the period 2010-2039 would increase with 0.4°C as mean comparing to the normal period and the most monthly increase on cold months of the year would be 1/4°C which corresponds to Fasa and Shiraz. The number of icy days (days with temperature equal to or <0°C) in the country would decrease and the number of hot days (with the maximum temperature of 30°C) in future period of the area would increase which the most monthly increase is related to November with 1.5 as the mean in a day.

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