Natural Environment Change, Vol. 2, No. 1, Winter & Spring 2016, pp. 47- 55

Spatiotemporal analysis of carbon dixoid impact on seasonal rainfall oscillation in Iran

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Recieved: January 27, 2015 Accepted: August 28, 2016

Abstract

Climate change disturbs the distribution of precipitation patterns and affects water resources. A lot of evidences imply that the increased atmospheric concentration of greenhouse gasses in turn increases the precipitation changes around the world. Thus, since Iran is located in an arid zone of the earth, identifying the effects of CO_2 concentrations on Iran precipitation rate is highly important in planning the projects for water resources. Statistical data from 31 selected synoptic stations between 1975-2010 have been used. Also data for CO_2 (ppm) were taken from the website of NOAA and then were analyzed by Pearson Correlation Coefficient (PCC). Our results indicate that CO_2 had a positive (incaresing) effect on the spring precipitation in the northern areas of Iran and a negative (decreasing) effect in the southern parts of the country. There is not a specific pattern for the distribution of precipitation in the summer; the related data were not much reliable. In the fall, CO2 had an increasing effect on the precipitation rate in the eastern parts and, conversly, a decreasing effect observed in the northern parts (particularly in the southwestern coast lines of the Caspian Sea). Finally, in the winter, precipitation rate showed an increasing pattern and, in some western and northeastern parts of the country, a decreasing pattern was observed.

Keywords

CO_2, global warming, greenhouse gass, Iran, precipitation.

1. Introduction

Human activities have raised carbon dioxide (CO_2) concentration in the atmosphere, and further rise seems inevitable during the next decades. Difficulties in quantifying climate feedbacks make the estimate of the global warming associated with increased CO_2 uncertain. These are of particular concern in the tropics where human welfare closely depends on rainfall. However, several studies have shown that CO_2 could also impact the atmosphere through fast adjustments independent of surface temperature changes. Climate change and its impacts on earth surface, associated with the increase in greenhouse gases and changes in global temperatures, radiation budget, and hydrological cycles, have increasingly attracted the attention of researches in different areas (Ramos et al., 2012). According to the forth IPPC report (IPCC, 2007), significant trends in temperature and precipitation were observed around the world but with different magnitudes. The impacts of those trends in the mid-term have been noted in several aspects.The greenhouse effect is one of the threatening phenomena whose side effects impact all around the world. This phenomenon has been present since the earth planet began to originate and it is accounted for as

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one of the earth properties. Several lines of evidence show that increase in greenhouse gases can alter the frequency of precipitation in various zones of the earth (Frei et al., 2005).

Due to the adverse effects of the greenhouse gases on earth's precipitation, researchers have studied these kinds of effects. Some results are given as follows.

Mitchell (1989) concluded that the doubling in CO_2 results in increase of temperature between 2.8 to 5.2˚k and growth of precipitation between 7.1 to 15%. Although the doubling in CO_2 results in precipitation growth, but increasing in precipitation is not similar at various locations. At the areas with high latitude, generally the precipitation and runoff increases, but at the areas with low latitude, depending on the region, precipitation increases or decreases. Althourh this increase and decrease is different locally from a model to another model.

Frei et al. (1998), with autumn warming simulation implementing the regional climate models around Europe, concluded that as the temperature increases to 2˚C, the moisture increases to 15% and resultt in precipitation over 30 mm will increase significantly.

Ramanthan and Feng (2009) concluded that increase in greenhouse gases and global warming results in decreasing the evaporation and precipitation.

Raupach and Fraser (2011) studied and examined climate change which showed that climate changes caused to fluctuation in the snow and precipitation rate and especially reducing in snow to precipitation ratio and also changes in soil moisture rate, the intensity, and frequency of storms, runoff, floods and during drought.

Ramos et al. (2012), with multivariate analysis of seasonal variation of temperature and precipitation over the past 60 years in the Mediterranean climate region of North East Spain, concluded that in all stations according to the different seasons, the temperature increases about 1.5 to 2.5˚, but the precipitation does not change significantly.

Based on defined scenarios, increased density of greenhouse gases in the Earth will have inappropriate effects on the climate elements. Therefore, identifying effects of CO_2 as a greenhouse gas in a country like Iran, that is located in the dry region of the planet, is of great importance in the planning of water resources. So, according to the above discussion, the purpose of the present study is detecting the role of CO_2 as one of the greenhouse gasses fluctuating precipitation variability in different regions of Iran.

2. Study area

The Islamic Republic of Iran, with a total land area of 1,648,195 square kilometres, lies between 25º 00´ and 39º 47´ N and 44º 02´ and 63º 20´ E. Thus, the southern half of the country is in the subtropical zone and the northern half of the country is in the temperate zone with a desert zone in the middle of the country at around 30º N. The country has on the north east side, the desert and steppe of Turkmenistan and on the south and south west side, the hot and arid Saudi Arabian peninsula (Fig. 1).

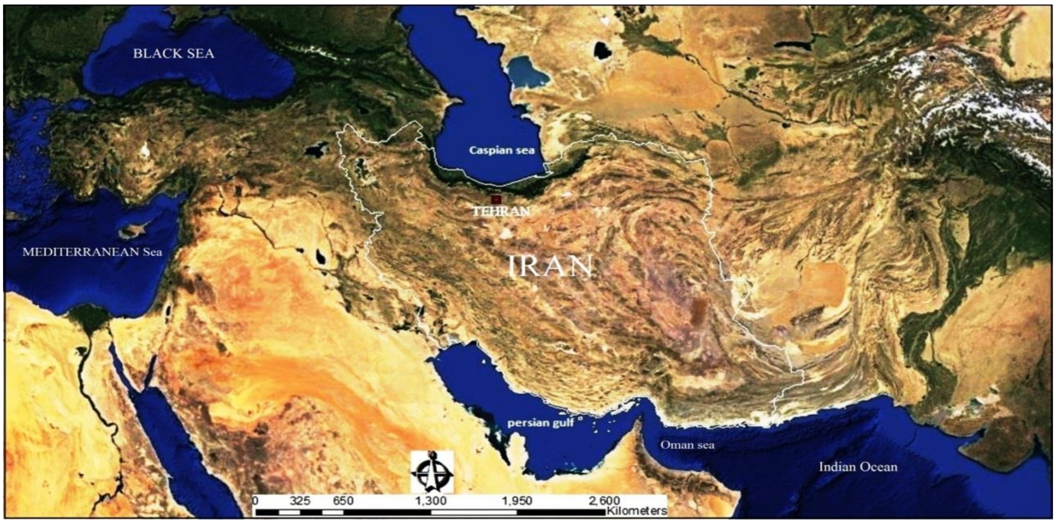

Fig. 1. Map of Iran as a study area

3. Materials and Method

In this study, longterm annual total precipitation data for 35-year period (1975 to 2010) were obtained from Iran Meteorological Organization (IMO) for 31 synpotic stations all over the country. The data of longterm concentration of CO_2 in ppm unite are obtained from NOAA website (*www.esrl.noaa.gov/gmd/dv/data*).

Correlation coefficient is a measure of association between two variables, and it ranges between –1 and 1. If the two variables are in perfect linear relationship, two different types of correlation coefficients are in use; one is called the Pearson correlation coefficient, and the other is called the Spearman rank correlation coefficient, which is based on the rank relationship between variables. The Pearson product-moment correlation coefficient is more widely used in measuring the association between two variables (Song, 2006). Given paired measurements (X_1,Y_1), (X_2,Y_2), ..., (X_n,Y_n), the Pearson correlation coefficient is a measure of association given by:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

Then, using obtained coefficients, plans to approach the Kriging ordinary with logic gaussian was prepared and drawn.

4. Results and Discussion

For analysing CO_2 gas effects in Iran seasonal precipitation oscillations, first the value of dispersion index and tendency to center of precipitation index for each station were determined. Then, correlation analysis of seasons of year was investigated. Analysis results are shown in the following tables and figures.

4.1. Analysis of CO_2 gas effect in winter precipitation oscillations

The relation between Winter precipitations and CO_2 gas was investigated. The calculated correlation coefficients are presented in Table 1.

According to Table 1, the PCC between winter precipitation and the winter amount of CO_2 in Sanandaj station is -0.403. The estimeted winter PCC is significant at α= 0.01, and this is the maximum correlation allocated between the stations themselves. This means that precipitation has an inverse relationship with CO_2 gas station that has been associated with a negative coefficient. Also in this season, most of the stations have a significant negative trend.

Table 1. Calculated Correlation coefficients between Winter precipitation of selected stations and CO_2

Statition Name	PCC	Statition Name	PCC
ABADAN	-0.152	KHORAMABAD	-0.212*
AHWAZ	-0.279**	MASHHAD	-.134
ARAK	0.106	OROUMIEH	0.085
BABOLSAR	-0.108	RASHT	-0.112
BAM	-0.026	SABZEVAR	-0.167*
BANDARABBAS	-0.179*	SANANDAJ	-0.403**
BANDARANZALI	-0.177*	SEMNAN	-0.061
BANDARLENGEH	-0.170*	SHAHREKORD	-0.062
BUSHEHR	-0.052	SHAHROUD	-0.035
BIRJAND	-0.064	SHIRAZ	-0.106
ESFAHAN	0.129	TABRIZ	-0.100
GHAZVIN	-0.084	TEHRAN	-0.079
GORGAN	-0.160*	YAZD	-0.184*
HAMEDAN	-0.118	ZAHEDAN	-0.100
KERMAN	-0.177*	ZANJAN	-0.228**
KERMANSHAH	-0.92	-	-

*.Correlation is significant at α 0.05.
**Correlation is significant at α 0.01 level.

In order to analyze the spatial distribution of CO_2 in the atmosphere affecting the relationship between the spatial distribution of Winter precipitation stations in Figure 2, the calculated correlation coefficients between CO_2 and precipitation stations in the study were drawn.

According to Figure 2, the spatial distribution of the results is as follows.

Stations that are located in the Western half of Iran showed the highest PCC between winter precipitation and CO_2 concentration. The low and high latitudes of the effects of CO_2 will be reduced by the amount of precipitation in winter. This means that the effect of CO_2 on the winter amount of precipitation in Southern Coast parts of eastern parts of the country is positive and additive and in northern parts of the country is the negative and decreasing. Meaning that the effect of this gas on the southern coasts and western regions of Iran winter precipitation and precipitation stations Sabzevar, Yazd, and Kerman is negative and positive relation of a reduction in the central part has been increasing. It also shows that amount of gas precipitation in other parts of the countries has not been affected.

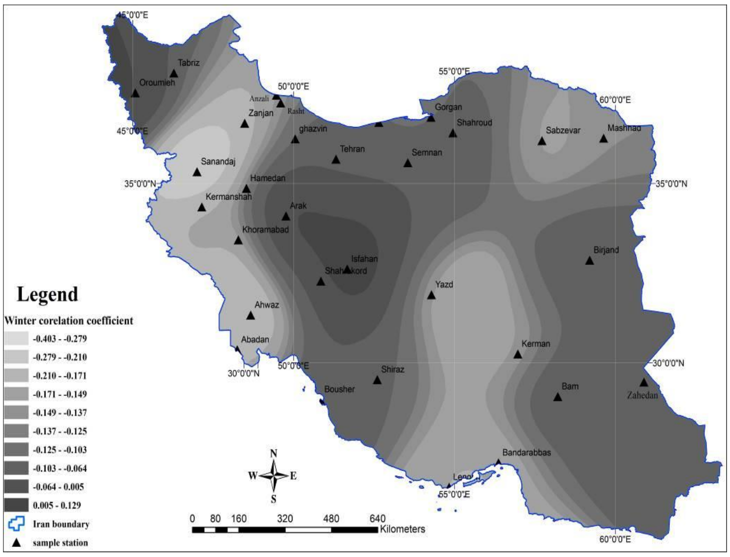

Fig. 2. Spatial distribution of the correlation between Winter precipitation and CO_2 Concentration

4.2. Analysis of CO_2 gas effect in spring precipitation oscillations

The relatoion between Spring precipitations and CO_2 was investigated, then calculated correlation coefficients are presented in Table 2.

Table 2. Calculated Correlation coefficients between Spring precipitation of selected stations and CO_2

Statition Name	PCC	Statition Name	PCC
ABADAN	-0.041	KHORAMABAD	0.016
AHWAZ	0.038	MASHHAD	-0.091
ARAK	-0.048	OROUMIEH	-0.067
BABOLSAR	-0.012	RASHT	0.048
BAM	-0.158	SABZEVAR	-0.059
BANDARABBAS	-0.213*	SANANDAJ	-0.082
BANDARANZALI	-0.018	SEMNAN	0.030
BANDARLENGEH	-0.165*	SHAHREKORD	0.015
BUSHEHR	-0.133	SHAHROUD	-0.112
BIRJAND	-0.150	SHIRAZ	-0.108
ESFAHAN	0.009	TABRIZ	-0.134
GHAZVIN	0.042	TEHRAN	0.067
GORGAN	-0.144	YAZD	-0.226**
HAMEDAN	0.014	ZAHEDAN	-0.048
KERMAN	-0.036	ZANJAN	0.011
KERMANSHAH	-0.021	-	-

*.Correlation is significant at α 0.05.

**.Correlation is significant at α 0.01 level.

According to Table 2, the correlation between seasonal precipitation and the amount of CO_2 spring in Yazd station -0.137 correlation at a significance level of 0.01 is the maximum correlation allocated between the stations themselves. This means that precipitation has an inverse relationship with CO_2 gas station that has been associated with a negative coefficient. In this season, as well as in Bandar Lengeh ensure 0.05 percent, CO_2 gas are inversely. The remaining stations have no significant relationship.

In order to analyze the spatial distribution of atmospheric CO_2 effects on spatial distribution of precipitation in study area, the calculated correlation coefficients between CO_2 and precipitation of stations were drawn in Figure 3.

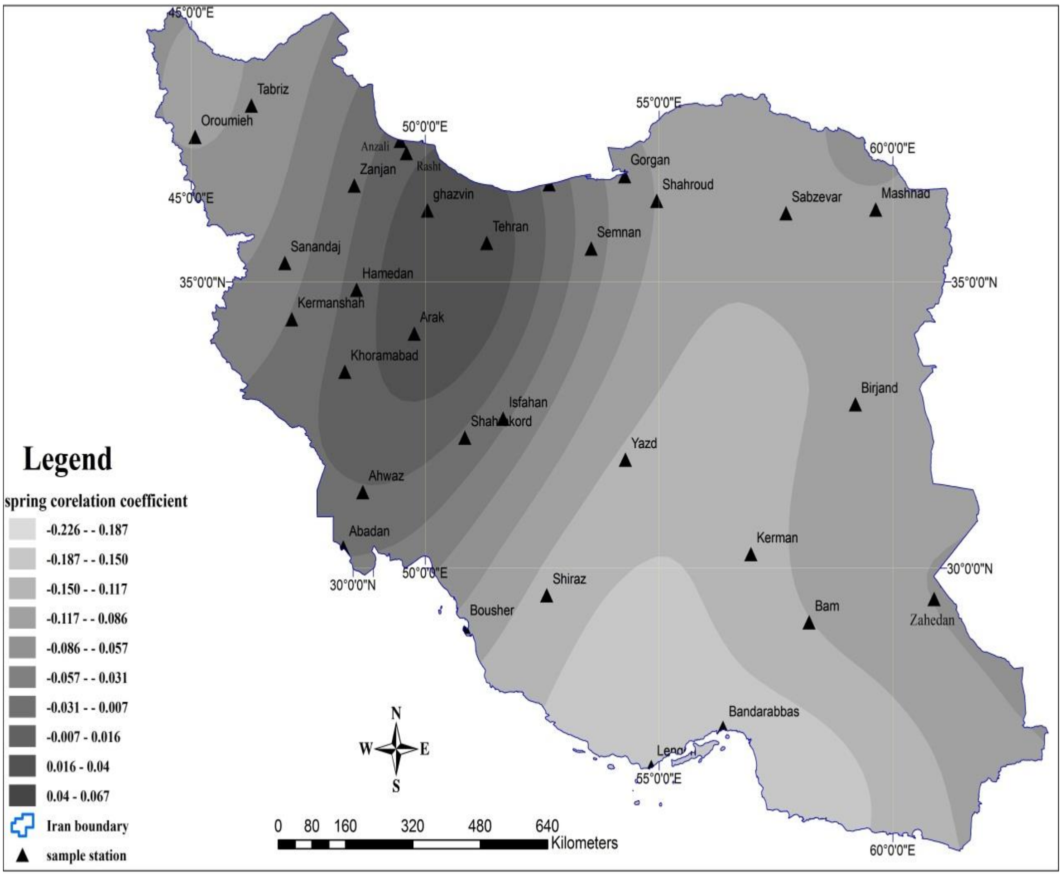

Fig. 3. Spatial distribution of the correlation between spring precipitation and CO_2 concentration

According to Figure 3, the spatial distribution of the results is as follows.

Stations in central parts and the southern half of the country in the spring show the most correlation with CO_2 gas. The low latitudes and high latitudes of the effects of CO_2 will be reduced by the amount of precipitation in the spring. This means that the effect of CO_2 on spring precipitation in southern and central parts of the semi-reduced is negative, it is positive in northern coast, and in other parts of the country are almost without unaffected.

4.3. Analysis of CO_2 gas effect in summer precipitation oscillations

The relation between Summer precipitations and CO_2 was investigated, then calculated correlation coefficients are presented in Table 3.

According to Table 3, the correlation between summer precipitation and the amount of seasonal CO_2 summer in Yazd station 0.232 correlation at a significance level of 0.01 is the maximum correlation allocated between the stations themselves. This means that precipitation has a direct relationship with CO_2 that has been associated with a positive coefficient. Stations in the northern half of the country, especially at a significance level of Zanjan station 0.01, trend correlation coefficient and the southern half of the stations have negative coefficients.

Table 3. Calculated PCC between Summer precipitation of selected stations and CO_2

Statition Name	PCC	Statition Name	PCC
ABADAN	-0.074	KHORAMABAD	0.207*
AHWAZ	0.033	MASHHAD	0.119
ARAK	0.121	OROUMIEH	0.120
BABOLSAR	-0.061	RASHT	-0.071
BAM	0.063	SABZEVAR	-0.091
B-ABBAS	-0.185*	SANANDAJ	0.124
B-ANZALI	0.015	SEMNAN	0.069
B-LENGEH	-0.143	SHAHREKORD	-0.064
BUSHEHR	0.058	SHAHROUD	0.144
BIRJAND	-0.007	SHIRAZ	0.071
ESFAHAN	0.028	TABRIZ	0.084
GHAZVIN	0.085	TEHRAN	0.101
GORGAN	-0.122	YAZD	0.008
HAMEDAN	0.232**	ZAHEDAN	-0.064
KERMAN	-0.162*	ZANJAN	0.228**
KERMANSHAH	0.160*	-	-

*.Correlation is significant at α 0.05.
**Correlation is significant at α 0.01 level.

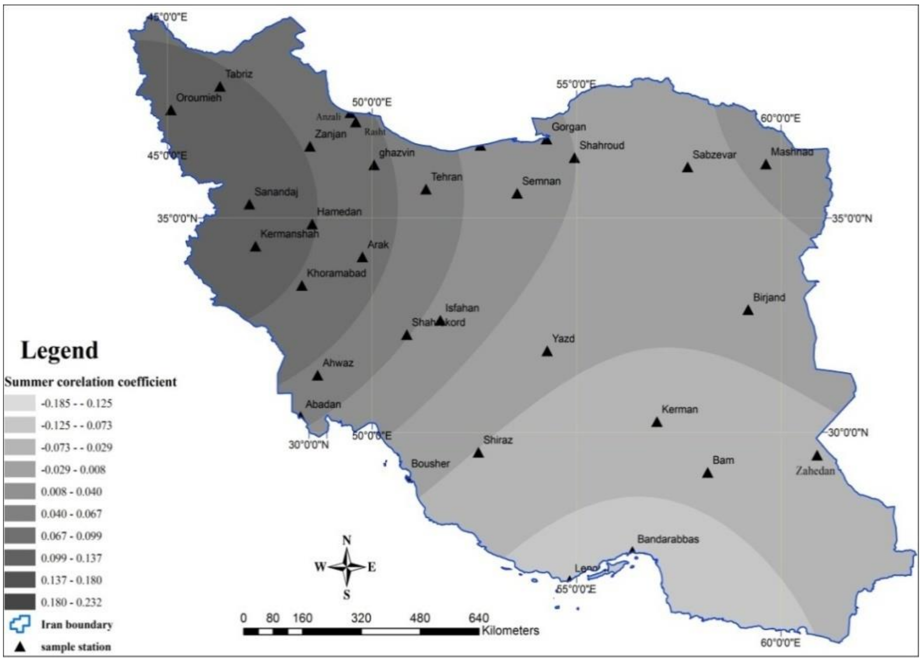

Fig. 4. Spatial distribution of the PCC between summer precipitation and CO_2 concentration

In order to analyze the spatial distribution of CO_2 in the atmosphere affecting the relationship between the spatial distribution of Summer precipitation stations in Figure 4, the calculated correlation coefficients between CO_2 and precipitation stations in the study were drawn.

According to Figure 4, the spatial distribution of the results is as follows.

Stations in the northern half of the country's largest summer show CO_2 gas. The low and high latitudes of the effects of CO_2 are added to the amount of precipitation in summer. This means that the impact on summer precipitation in the southern half of the country's gas and reduction of negative, positive and in other parts of the West and North West parts of the country has been almost unaffected.

4.4. Analysis of CO_2 gas effect in fall precipitation oscillations

The relation between fall precipitations and CO_2 gas was investigated then calculated correlation coefficients are presented in Table 4.

Table 4. Calculated Correlation coefficients between Fall precipitation of selected stations and CO_2

Statition Name	PCC	Statition Name	PCC
ABADAN	-0.019	KHORAMABAD	-0.017
AHWAZ	-0.043	MASHHAD	-0.156
ARAK	-0.184*	OROUMIEH	-0.122
BABOLSAR	-0.015	RASHT	-0.175*
BAM	0.003	SABZEVAR	-0.106
BANDARABBAS	-0.050	SANANDAJ	-0.172*
BANDARANZALI	-0.239**	SEMNAN	-0.016
BANDARLENGEH	-0.045	SHAHREKORD	-0.024
BUSHEHR	-.113	SHAHROUD	-0.111
BIRJAND	-.067	SHIRAZ	0.002
ESFAHAN	-0.037	TABRIZ	-0.157
GHAZVIN	-0.081	TEHRAN	-0.055
GORGAN	-0.155	YAZD	-0.001
HAMEDAN	0.001	ZAHEDAN	0.102
KERMAN	-0.029	ZANJAN	-0.068
KERMANSHAH	-0.123	-	-

*.Correlation is significant at α 0.05.
**.Correlation is significant at α 0.01 level.

According to Table 4, the PCC between between fall precipitation and the amount of seasonal CO_2 in Fall Yazd station -0.239 correlation at a significance level of 0.01 is the maximum correlation allocated between the stations themselves. This means that precipitation has an inverse relationship with CO_2 gas station that has been associated with a negative coefficient. Also in this season, precipitation stations in Sanandaj, Arak, and Tehran at a confidence level of 0.05 percent, CO_2 gas are inversely stations, and the southern half station of the country does not have a significant level.

In order to analyze the spatial distribution of CO_2 in the atmosphere affecting the relationship between the spatial distribution of fall precipitation stations in Figure 5, the calculated PCC between CO_2 and precipitation stations in the study were drawn.

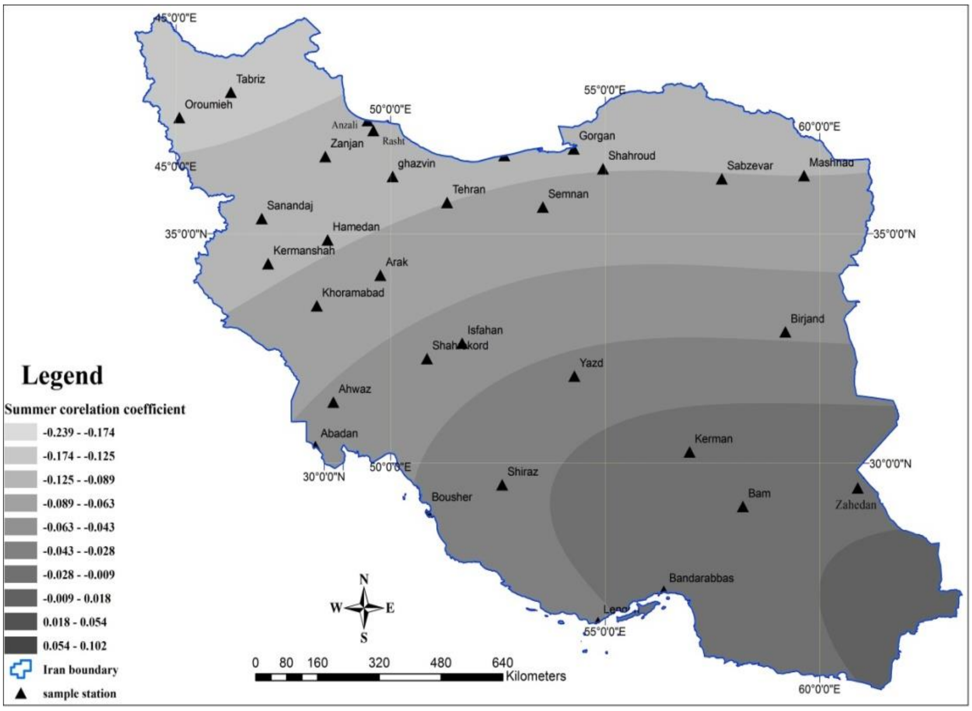

Fig. 5. Spatial distribution of the correlation between Fall precipitation and CO_2 concentration

According to Figure 5, the spatial distribution of the results is as follows.

Stations in the northern half of the country's largest fall show with CO_2 gas. The low and high latitudes of the effects of CO_2 will be reduced by the amount of precipitation in this season. This means that the effect of this gas on the amount precipitation fall in parts of eastern and northern parts of the country incremental positive and negative this impact of decline. It also shows that gas in precipitation parts of central, western and southern countries have been unaffected.

4.5. Relationship between seasonal precipitation in Iran and atmospheric CO_2

The relatoion between seasonal total precipitation in Iran (all satations avrege) and atmospheric CO_2 was analyzed then calculated correlation coefficients are presented in Table 5.

According to Table 5, relatinship between fall and winter precipitation in Iran and atmospheric CO_2 is significant at the 0.05 level. Iran total mean prcipitation in spring and summer seasons does not have significant temporal trend, but in fall and winter cold seasons Iran precipitation have temporal decreased trends. Iran decrased temporal trends and exponantial incerased trends of CO_2 in fall and winter are shown in Figure 6.

Table 5. Calculated PCC between Iran seasonal precipitains and atmospheric CO_2 cocentrations

Season	PCC	Season	PCC
Spring	-0.09	Summer	-0.078
Fall	-0.341*	Winter	-0.389*

*.Correlation is significant at α 0.05

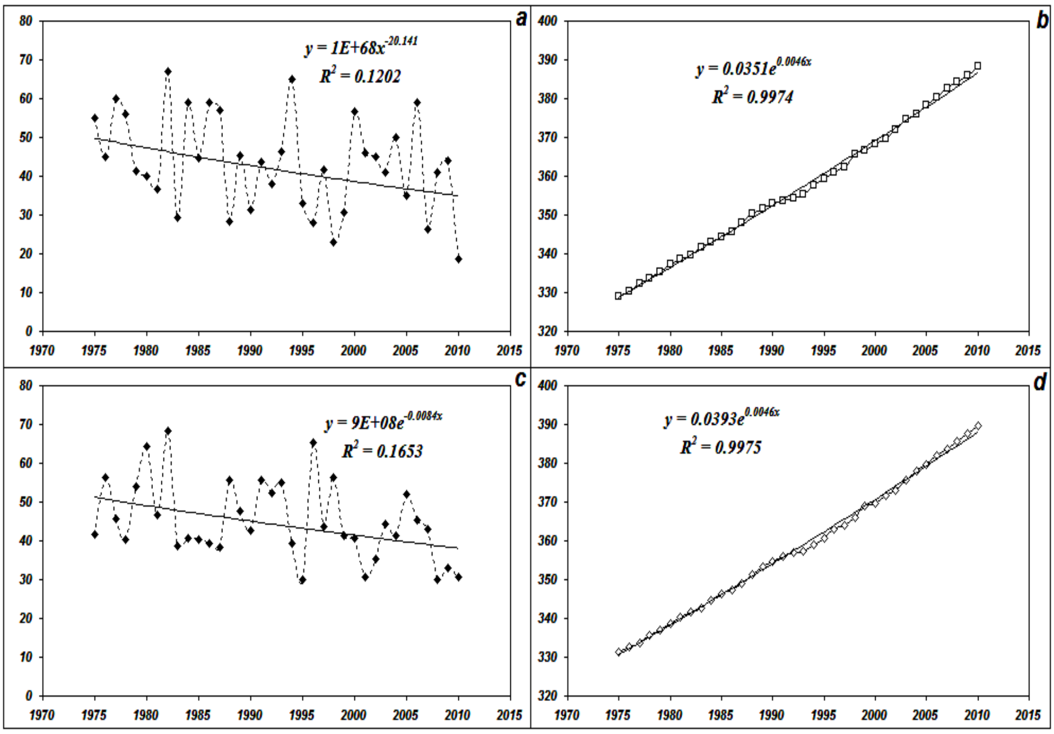

Fig. 6. Signifitant temporal exponantial trends for fall (a) and winter (b) and atmospheric CO_2 in fall (c) and winter (d). value unit are for precipitatin in mm and CO_2 in ppm

5. Conclusions

With regard to research findings, the consequences of analysis of CO_2 effects on seasonal precipitation oscillation in different regions of Iran, we can conclude that CO_2 had positive effect on the amount of precipitation in northern areas of Iran and in southern areas CO_2 reduced the precipitation. Although, in summer, the precipitation of some parts of western area of Iran have been influenced by CO_2 and consequently, causes the increase of precipitation, the precipitation has not followed a regular pattern because summer is considered a dry season in Iran, so the results of this research cannot be reliable. During statistical period from 1975 to 2010, in fall, the effect of CO_2 and precipitation in eastern area of Iran was positive in form of increase in precipitation, whereas in northern areas, especially in the west coast of Caspian Sea the effect of this gas was reversed and caused the reduction in precipitation, whereas naturally this area receives the most amount of precipitation in different regions of Iran in this season. In winter, the amount of precipitation is the most in comparison with other seasons and normally most of the meteorological stations are faced with precipitation occurrence but during this statistical period and by taking into account the study of the effect of CO_2 on this season's precipitation, the precipitation in central area's stations has been positive and in form of increase in precipitation and some parts in the west and north-east of Iran have received negative and decreasing effect, all in with regard to the above mentioned results we can say that CO_2 has exerted its influence on seasonal precipitation in form of reduction in most regions in Iran and only in some parts of the east it has had increasing effect. It should be noted that this relationship will not only be the effect of CO_2 on rainfall, so that it may be bilateral relations. so that it may be two-sided relations. Therefore, it is recommended that the results will be analyzed more deeply in future studies.

Acknowledgements
The authors are very grateful to the anonymous referees for their encouragement, helpful suggestions, and constructive comments, which resulted in this improved manuscript.

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