EVIDENCE OF GLOBAL WARMING FROM ZAKHO PRECIPITATION DATA

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Abstract

Analysis of available precipitations data for Zakho area supports the argument that global warming has affected this region. Results shows that monthly and yearly rain fall have been decreasing systematically since the thirties of the last century until now. Based on linear correlation model, some future estimations of the reduction in precipitation as related to the global atmospheric carbon dioxide concentrations are made.

Introduction

Although the name of global warming has appeared for first time about forty years ago during the seventies of the last century [Möller,1963; Lorenz,1970; Bryson and Wayne, 1970], the idea that human activities can affect the climate has much deeper roots in human history. Some scholars have even argued that it goes back to the ancient Greek civilization [Neumann, 1985]. However, the idea that there is a direct link between atmospheric carbon dioxide concentration and climate change was first advocated by the Swedish scientist Arrhenius [Arrhenius, 1896] who argued that decreasing CO_2 levels in the atmosphere by half can bring back Europe to an ice age.

Results of intensive scientific works performed during the seventies and eighties of the last century pointed in the direction that there may be a direct link between atmospheric CO_2 levels and the earth climate. This induced the world community to establish the "Intergovernmental Panel on Climate Change" IPCC in 1988. The IPCC used all published results related to climate change to build its famous 2007 report [Climate Change 2007]. One main conclusion in this report is that there is at least 90% probability that the earth climate is getting warmer as a result of the increase of CO_2 emissions. Many other research works disputed this result arguing that the observed climate change is a natural phenomenon that can be attributed to cyclic weather changes or sun activity [Balling, 2003; Glassman, 2010; Bernaerts, 2009]. A good list of references related to both sides of the argument can be found in reference [Khandekar,2007].

Almost yearly world submits were held during the period 1993 – 2012 to try to hammer international agreements on how to limit the fast increase in atmospheric CO_2 levels. Unfortunately, no such effective agreement is within sight.

1993 Rio de Janeiro Brazil
1995 – The Berlin Mandate Berlin Germany
1996 – Geneva, Switzerland
1997 – The Kyoto Protocol on Climate Change Kyoto Canada
1998 – Buenos Aires, Argentina
1999 – Bonn, Germany
2000 – The Hague, Netherlands
2001 – bis, Bonn, Germany
2001 – Marrakech, Morocco
2002 – New Delhi, India
2003 – Milan, Italy
2004 – Buenos Aires, Argentina
2005 – Montreal, Canada
2006 – Nairobi, Kenya
2007 – Bali, Indonesia
2008 – Poznań, Poland
2009 – Copenhagen, Denmark
2010 – Cancún, Mexico
2011 – South Africa
2012 _ Doha Qatar

Many studied related to local manifestations of climate change in many parts of the world have been performed [Borna *et. al.*, 2011; Mall *et. al.*, 2006; Busuioc *et. al.*, 2007; Evans, 2010]. These four references are only examples of this type of work and there are far many others which space limits their citation here. Most such works were carried out by native researchers of the local region concerned using locally collected meteorological data.

Qualitative evidences related to some kind of warming effects in Kurdistan in general have been observed. The most obvious effects of such warming are the late start of rain fall in some years, and the drying of some water springs in the region. Although no quantitative evaluations of these effects have been made up to our knowledge, it is widely noticed that the serials plantation season is at least two to three weeks late compared to few decades back. It is our purpose here to investigate if there are any evidences that global warming is affecting Zakho region. This work is part of a wider study covering the whole Kurdistan region.

The Data

Any study of global warming manifestations in any region must be based on meteorological data covering the maximum possible span in time. For some parts of the world, such data covering over 300 years are available. However, such luxury exists in the highly developed world only. The situation with data for Kurdistan region is not as so comforting. Even so, a reasonable volume of data related to precipitation and monthly temperatures for a good number of years could be compiled in the process of this work. The main sources of our data for this work are:

- Monthly rain fall data covering the years 1935 – 1958. These were obtained from the United States National Oceanic and Atmospheric Administration (NOAA)

[http://docs.lib.noaa.gov/rescue/data_rescue_iraq.htm]. These data were originally prepared over the years by the meteorological office which was then, an establishment of the Iraqi Ministry of Works and Transport. The data are contained in a document supplied by the Iraq Development Board to the association of Harza Engineering Company of Chicago and Bennie Deacon and Gourley Company of London as part of the requirements to prepare a hydro-geological survey of Iraq. The document was digitized in 1999 as part of NOAA Environmental Data Rescue Program. Data related to Zakho and all other Kurdistan locations are manually entered to MATLAB data files.

- Monthly rain fall data for the period 1980 – 2012 are obtained from Duhok Meteorological Office and Seismology. These are entered on the same MATLAB data files mentioned above. No data could be found for the period 1958 – 1979.

Analysis and results

Special MATLAB execution program is written to analyze monthly rain fall data extending over any number of years in any location. The program reads the data, excludes any missing entries for a particular month from the analysis, and starts to perform linear correlation analysis. This correlation analysis can be performed against either the year number or the atmospheric monthly CO_2 concentration. The latter is obtained from the NOAA publications [ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_mm_mlo.txt]. The data for each month are fitted to a straight line using MATLAB fitting facility which produces fits with over 95% confidence level. Results are presented in figures (1 to 8). Figure (9) shows the total rain fall in mm per year under study plotted against year number in (a) and against CO_2 concentration in (b). It is worth noting here that fitted straight lines in all cases appear to have negative slopes. This is an indication that the general behavior shows a reduction in rain fall with time.

Data for summer months of June, July, August, and September are not presented because rain fall during these months is very rare and no representative fitting could be obtained. It is also worth mentioning that the data in figures (6, 7, and 8) do not include those (October, November, and December) for the year 2012 as they are not available yet.

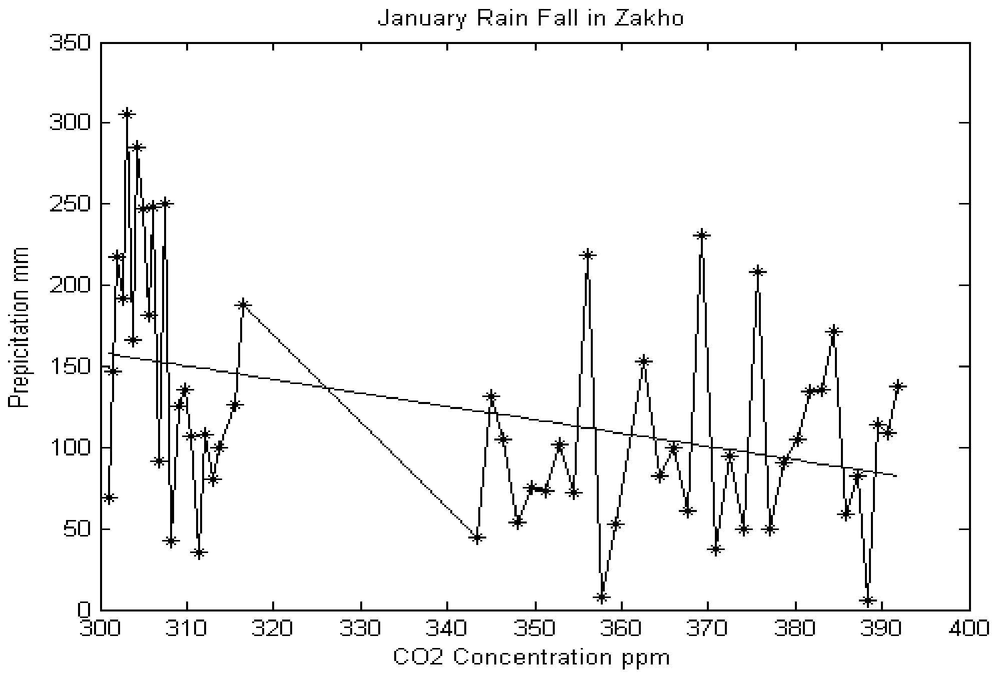


Figure (1) January rain fall in Zakho between 1935 and 2012 plotted against CO_2 concentration for each year. (*) data, solid line linear fit

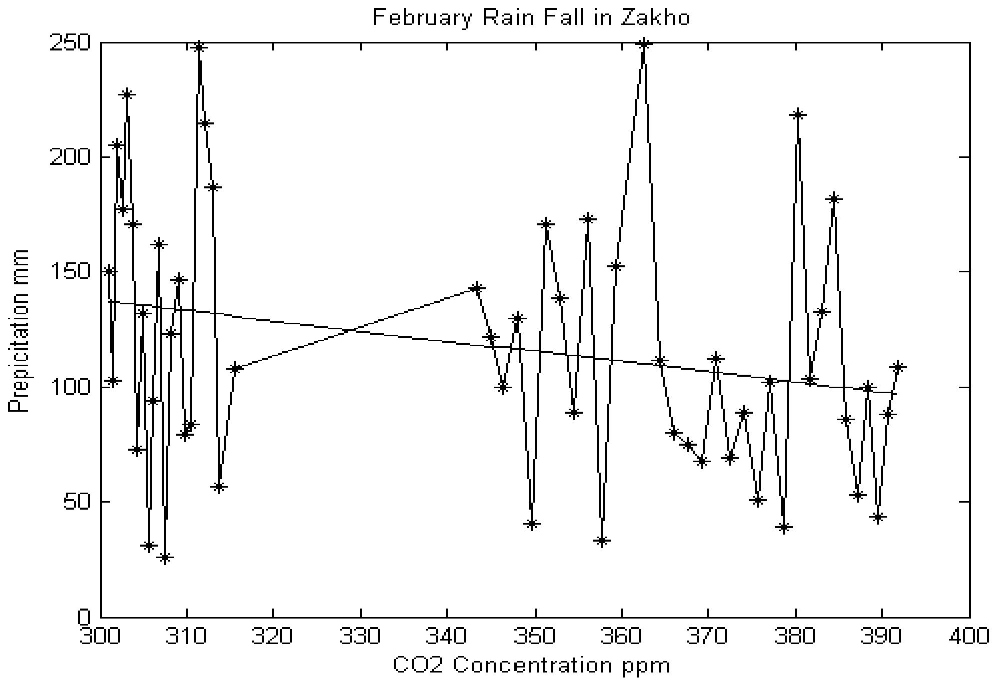


Figure (2) February rain fall in Zakho between 1935 and 2012 plotted against CO_2 concentration for each year. (*) data, solid line linear fit

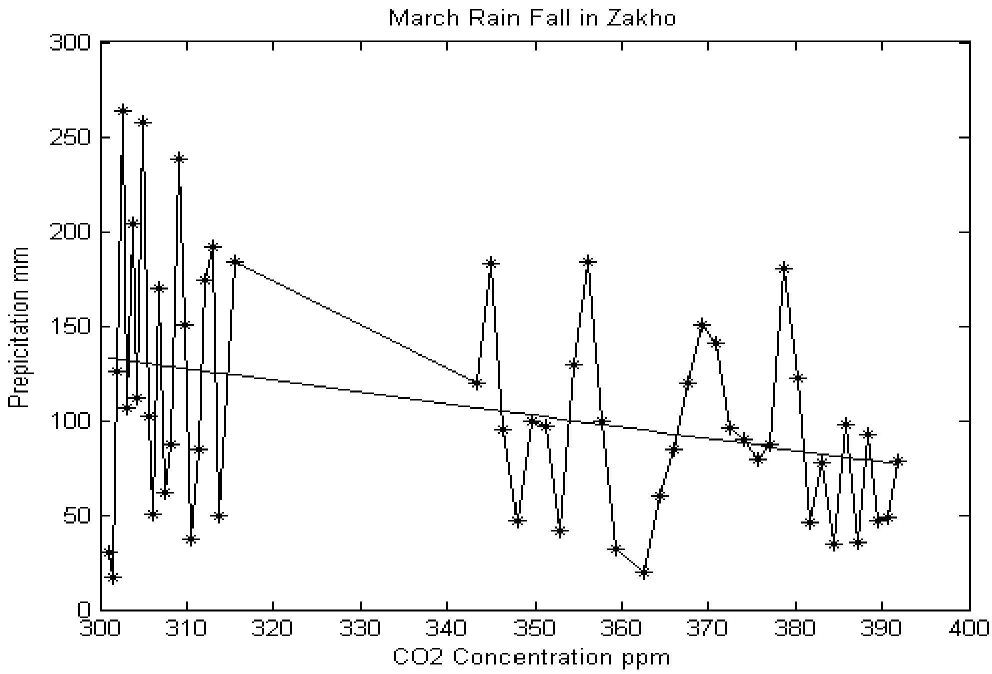


Figure (3) March rain fall in Zakho between 1935 and 2012 plotted against CO_2 concentration for each year. (*) data, solid line linear fit

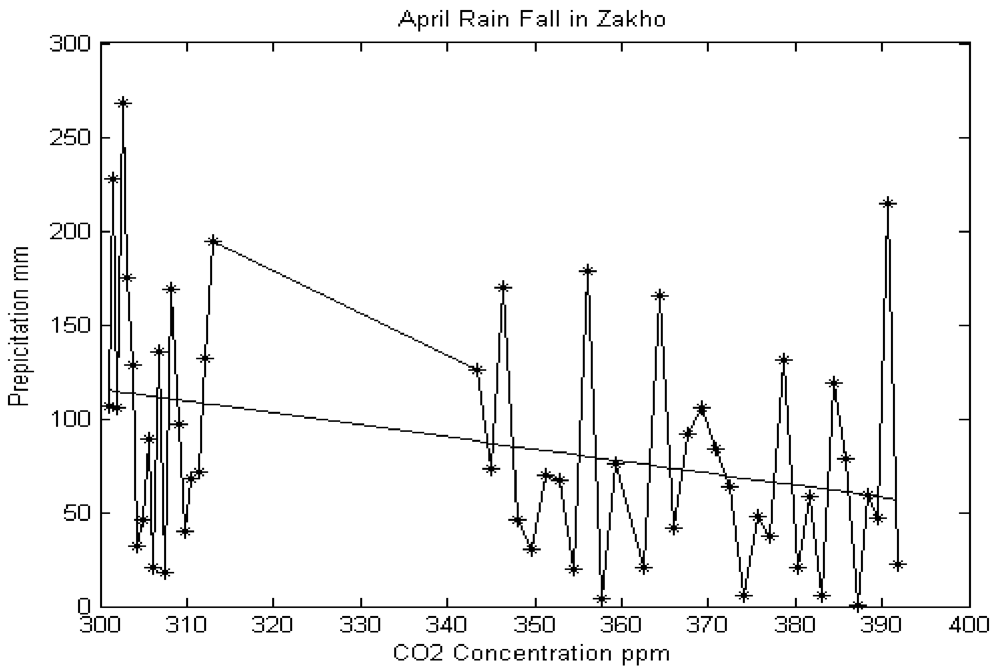


Figure (4) April rain fall in Zakho between 1935 and 2012 plotted against CO_2 concentration for each year. (*) data, solid line linear fit

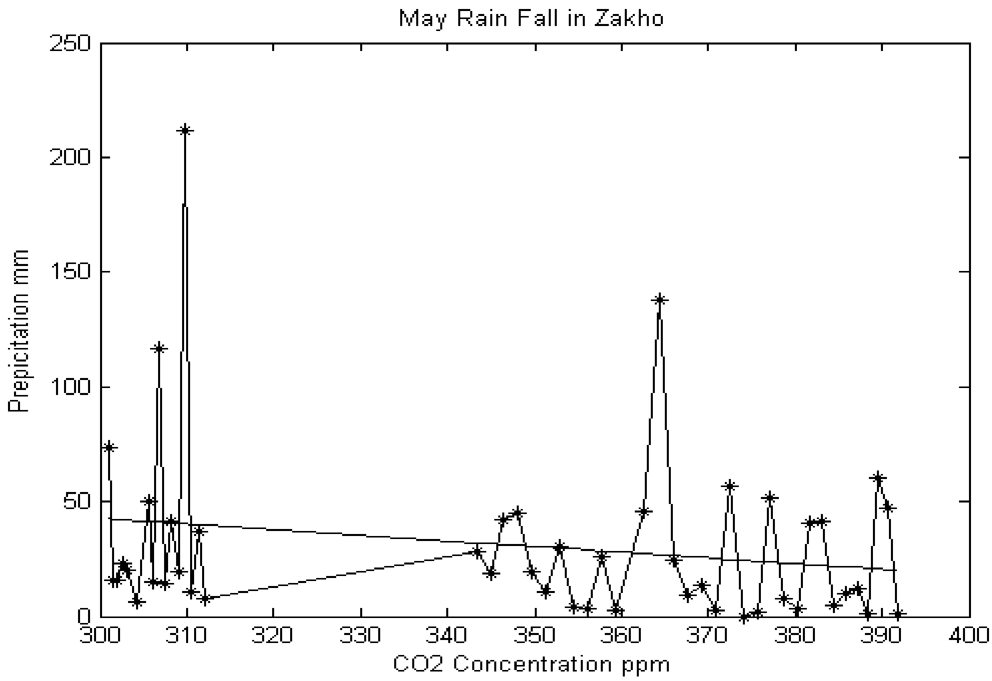


Figure (5) May rain fall in Zakho between 1935 and 2012 plotted against CO_2 concentration for each year. (*) data, solid line linear fit

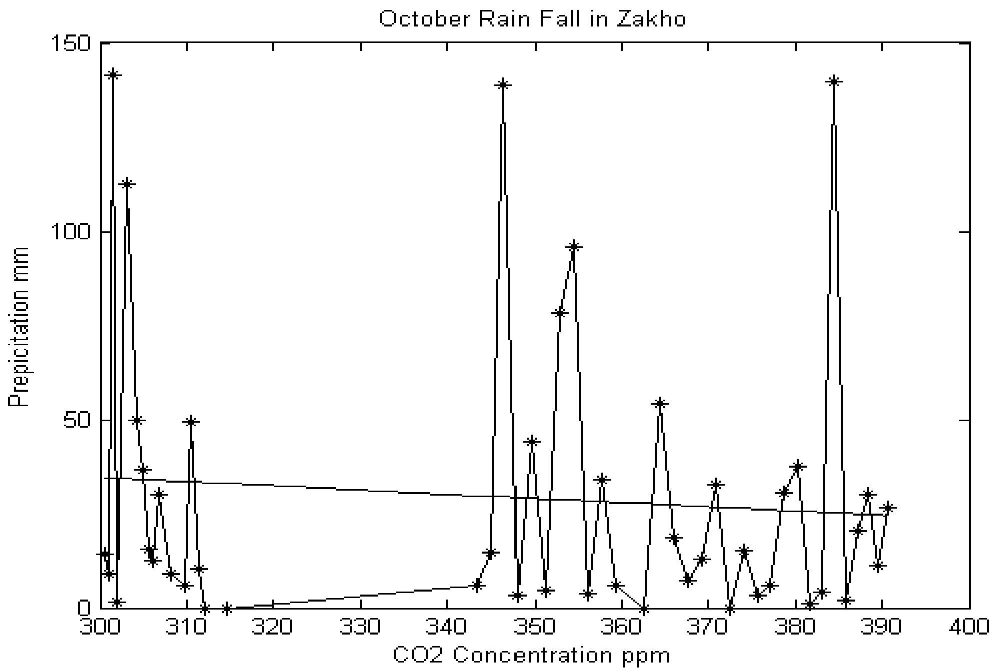


Figure (6) October rain fall in Zakho between 1935 and 2011 plotted against CO_2 concentration for each year. (*) data, solid line linear fit

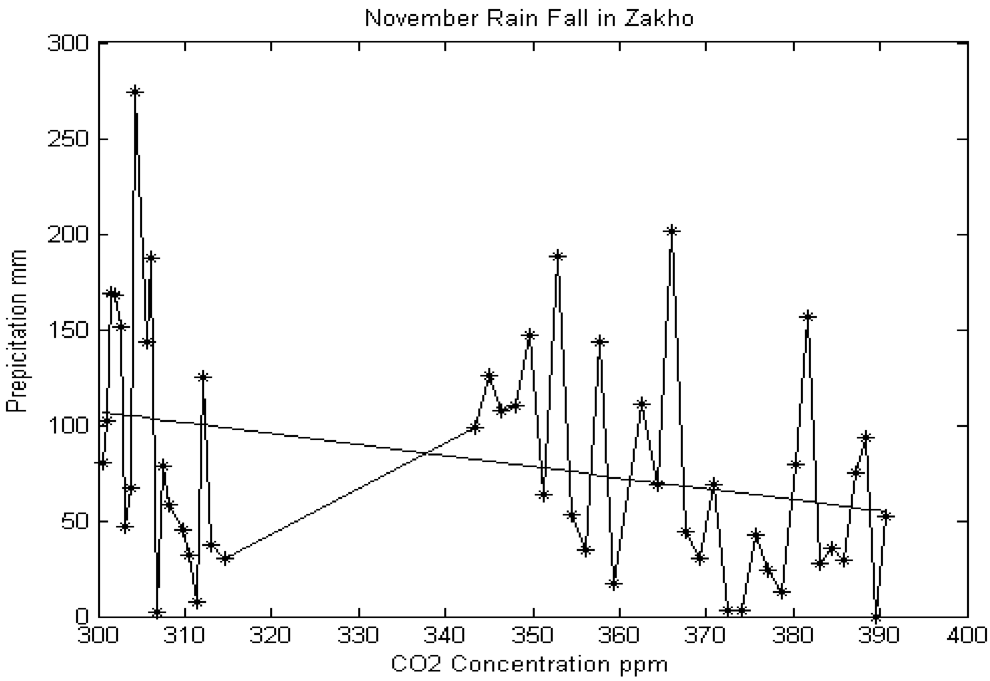


Figure (7) November rain fall in Zakho between 1935 and 2011 plotted against CO_2 concentration for each year. (*) data, solid line linear fit

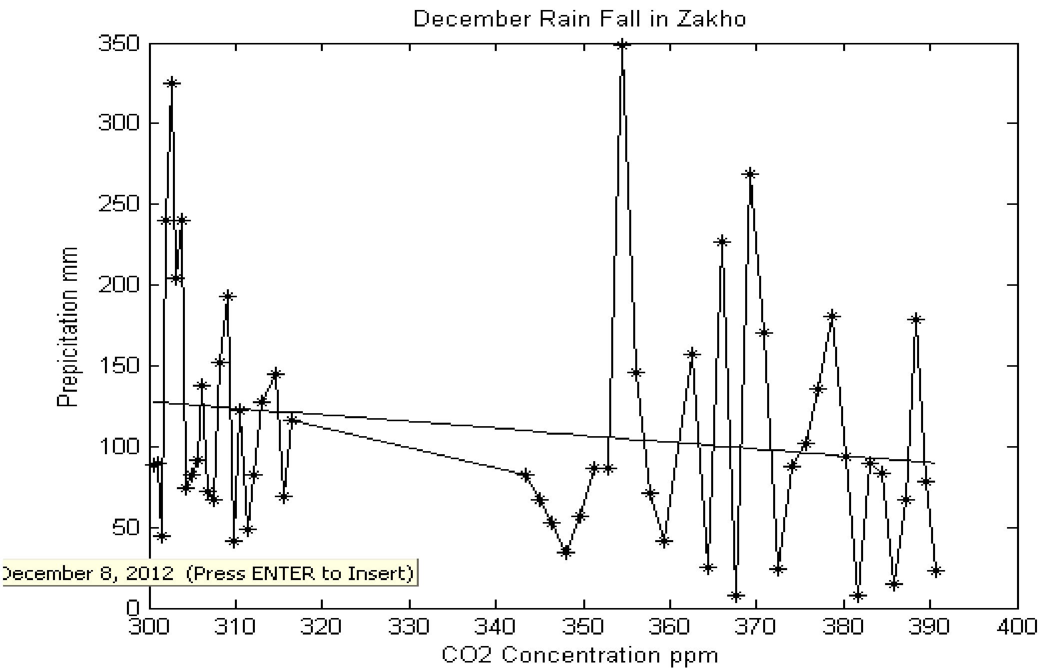
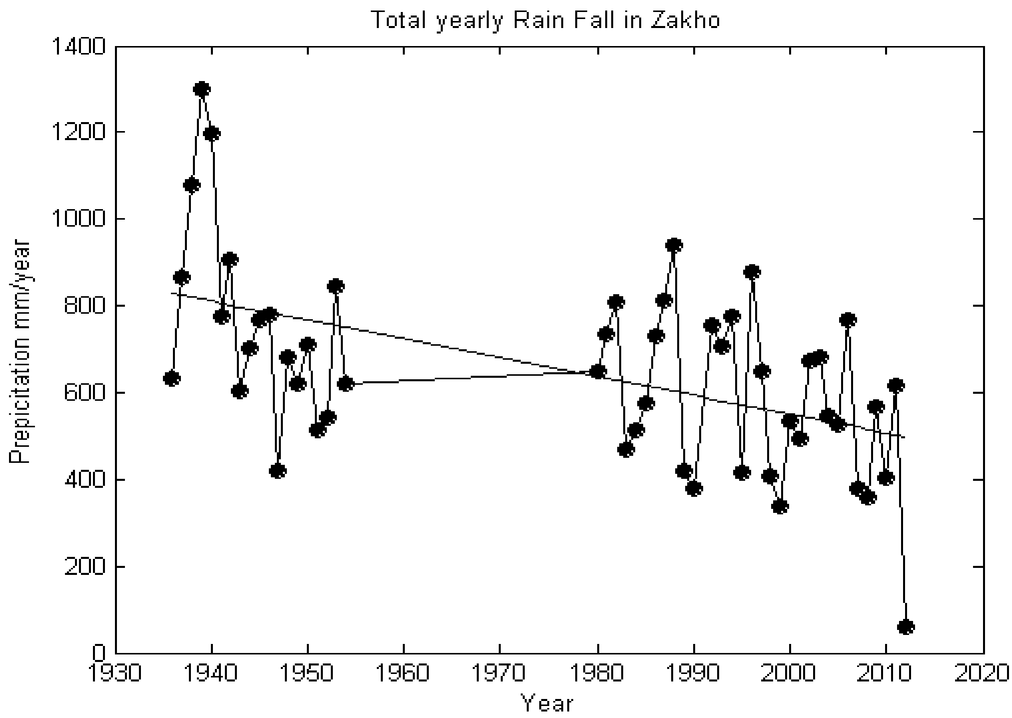
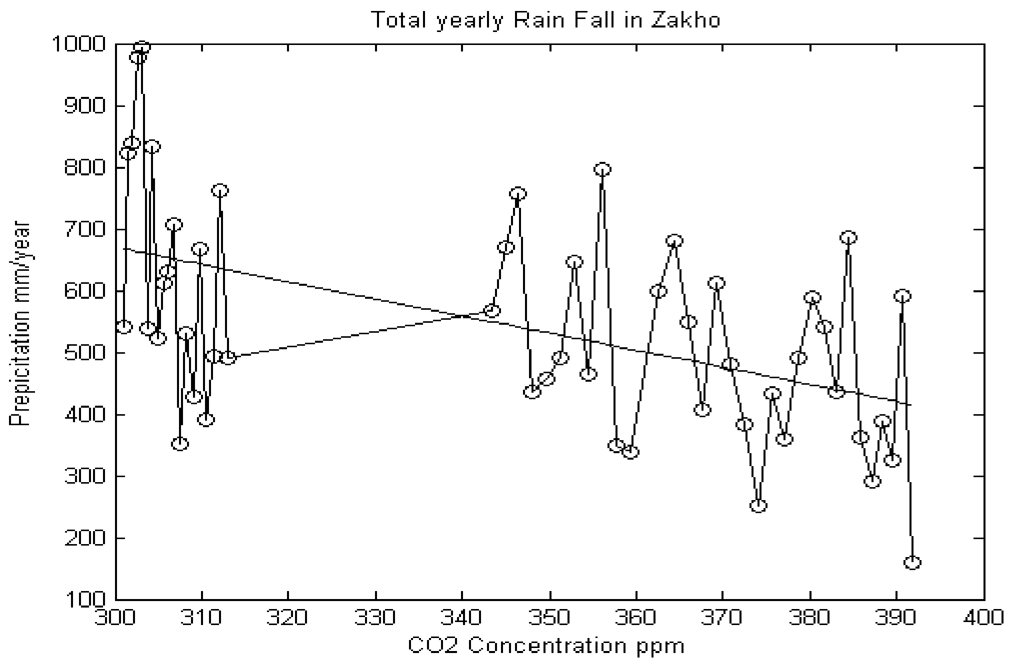


Figure (8) December rain fall in Zakho between 1935 and 2011 plotted against CO_2 concentration for each year. (*) data, solid line linear fit



(a)



(b)

Figure (9) Total yearly rain fall in Zakho between 1935 and 2011 plotted against (a) year number, (b) CO_2 concentrations. (Circles) data, solid line linear fit

Discussion

All results above indicate that rain fall in Zakho area have been generally decreasing for all rainy months over the past eighty years. However, the rate of this decrease varies from one month to another. Figure (10) shows the slopes of the straight line fitted above, plotted against month numbers. It is clear from this figure that the maximum negative slopes are those for January, February, and March. This means that winter months are more affected by global warming than spring and autumn months.

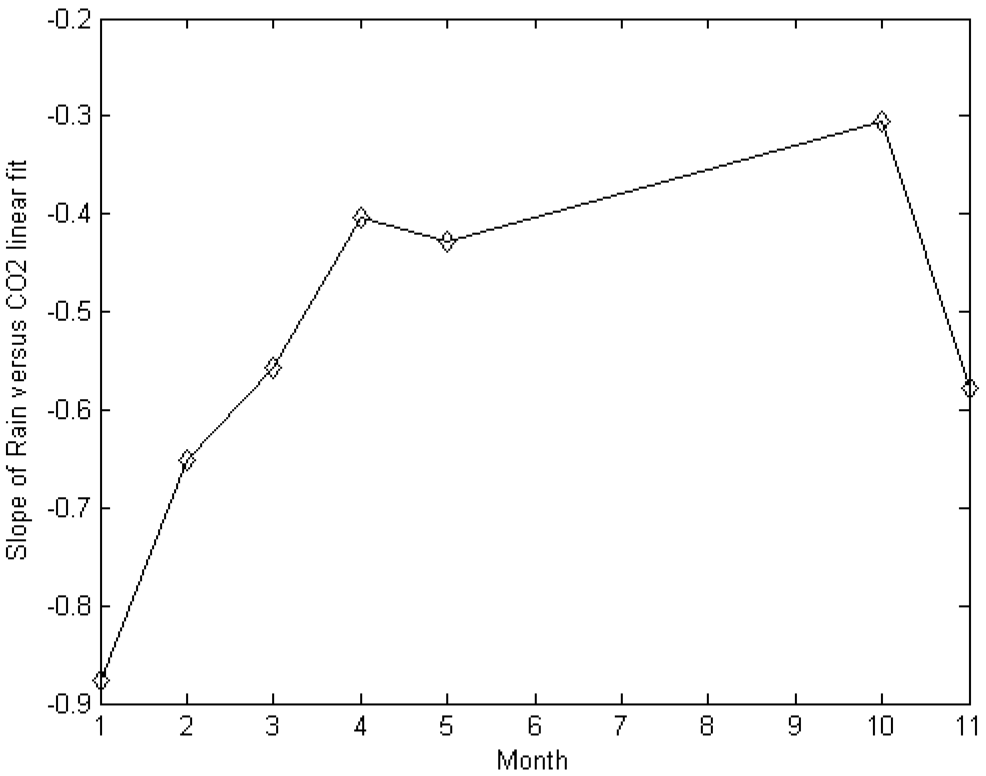


Figure (10) Slopes of straight lines fitted in figures (1 to 8) plotted against month number.

The over all fit of the yearly rain fall (which is the sum of all months) plotted and fitted in figure (9-b) has slope of -2.7781. This means that there is about 2.8 mm reduction in the amount of rain that falls in a year for every one part per million increases in global atmospheric CO_2 level.

These results may encourage one to make some speculations about the future trend of rain fall in Zakho area. Any such speculation must be based of course on the CO_2 levels future trends. Figure (11) shows the international data for CO_2 levels as published by United Nations Environment Programme (UNEP) [http://www.grida.no/publications/vg/climate/page/3062.aspx]. Two interesting points can be seen from this figure. The first is that CO_2 concentrations have been on the rise, year after year, since the start of the industrial revolution. The second is that this rise has slightly weakened over the few years following 1993. This is demonstrated by the facts that while all data before 1993 could be reasonably fitted to an exponential equation, the data post 1993 tend to significantly deviate from the exponential form. This is interesting in the sense that it may be considered as an indication that the Kyoto agreement may have had some positive effect in limiting the previous fast increase in CO_2 levels. Instead, the data can be well fitted to the empirical equation of the form

$$CO_2\,(ppm) = 121\tanh\left[e^{\frac{(y-2000)}{32.8}}\right] + 284.1 \quad (1)$$

The numerical values in this equation represent the result of performing nonlinear fitting on the measured data, and (y) represents the year number.

Considering that the present trend in CO_2 levels will continue up to 2020, then one reaches the estimation that by the year 2020, the average total rain per year will fall to about 395 mm. This represents a reduction by about 27% from the overall average of the last eighty years of about 543 mm. This result may look striking, but this can be further demonstrated if one considers the average rain fall for the years 1935-1958 which is about 638 mm compared to the average for the year 1991-2011 which is about 487 mm. However, the standard deviation associated with these averages is about 150 mm. This gives the above speculations about 90% confidence level.

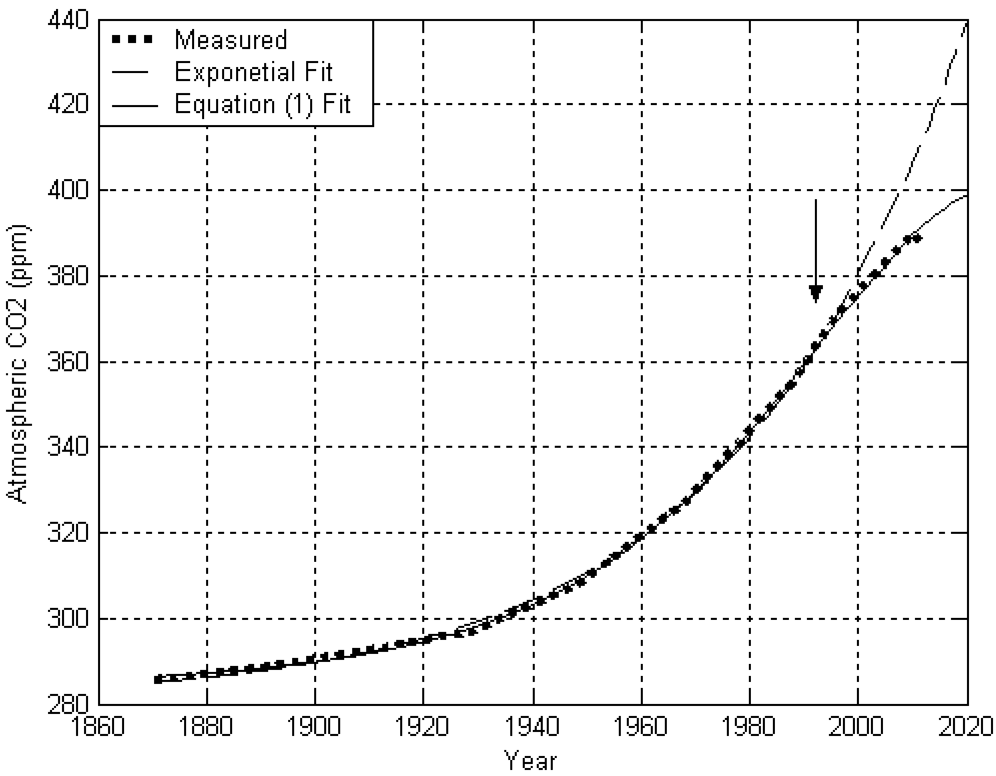


Figure (11) Average annual CO_2 atmospheric concentrations [17]

Conclusions

Analysis of rain fall data clearly demonstrates that the amount of rain in Zakho area has been on the decline over the past eighty years. If one accepts the argument that this reduction is a direct result of increased atmospheric CO_2 levels, then one would reasonably expect the rain fall to decrease by about 27% by the year 2020. The direct medium and long range agriculture, economical, geographical habitats, and social consequences of such reduction have to be fully studied.

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ألأدلة على ألأحتباس ألحراري من بيانات امطار منطقة زاخو

الملخص

يؤيد تحليل البيانات المتوفرة عن كميات الامطار الساقطة في منطقة زاخو الحجج القائلة بان الاحتباس الحراري العالمي قد اثر على هذه المنطقة. أظهرت النتائج ان كميات الامطار الشهرية والسنوية قد اظهرت انخفاضا نظاميا منذ ثلاثينيات القرن الماضي وحتى الوقت الحاضر. واعتمادا على نموذج الترابط الخطي فقد تم وضع بعض التوقعات الخاصة بالانخفاضات المستقبلية لكميات الامطار بناء على الزيادات المتوقعة لتراكيز ثاني اوكسيد الكربون في الغلاف الجوي للكرة الارضية

بەلگە لسەر گەرمبوونا ئەردى ژ داتایێن بارینا بارانا لدەڤەرا زاخۆ

كورتی

شيتەلكرنا داتایێن ب دەست مەڤەهاتين لسەر رێژا بارینا بارانا لدەڤەرا زاخو پشتگێریا هندێ دكەن كو گەرمبوونا ئەردی كارتێكرنا لسەركری. ئەنجام هوسا دياربوينە كو رێژا بارینا بارانا هەيڤانە وسالەنە ب شێوەكێ رێك كێم بوينە ژ هەر ساليێن سيهان ژ چەرخێ بيستێ وهەتا نوكە. پشت بەستی پ موديلێ گرێدانا هێلی، هندەك پێشبينيێن تايبەت ب كێمبوونا رێژا بارانا هاتنەكرن ل پاشەرۆژێ پالپشتی ب زێدەبوونا پێشبينی كری يا رێژا دووانی ئوكسيدی كاربون د بەركێ ئەرديدا.