Precipitation trends in Baghdad Governorate, Iraq

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المستخلص:

تم دراسة التباين الزمني لهطول الامطار احصائيا بتطبيق أسلوب الفروق التراكمية Cumulation_ (Deviation) لمحافظة بغداد لمدة (٨١) عاما من (١٩٣٧ – ٢٠١٨) لتحديد اتجاه كميات الامطار، وكشف التحليل عن وجود تذبذب وانخفاض كبير في كميات الامطار، وترتبط هذه التغيرات بارتفاع مستويات ثاني أوكسيد الكربون والغازات الدفيئة الناجمة عن الأنشطة البشرية وخاصة في فترة التسعينيات حيث تأثرت الهيدرولوجيا بالتقلبات المناخية.

الكلمات المفتاحية: اتجاهات الهطول، هطول الأمطار في بغداد، التقلبات المناخية، الفروق التراكمية، الهيدرولوجيا.

Abstract:

This study statically investigates the temporal variation of rainfalls in Baghdad governorate over a period of ٨١ years (١٩٣٧ - ٢٠١٨) using the Cumulative Deviation approach. The results reveal a volatility and a significant decrease in rainfall amounts. These changes are mainly linked to the increase in atmospheric carbon dioxide levels and greenhouse gases caused by human activities, that have contributed to global climate change. The study highlights the impact of these shifts on Baghdad's hydrological patterns, particularly during the ١٩٩٠s. The effects on water resources, agriculture, and infrastructure in the region are also examined.

Keywords: Precipitation trends, Baghdad rainfall, climate variability, cumulative deviation, hydrology.

Introduction

The word 'Climate' refers to the weather conditions throughout an era, whereas the word 'weather' describes a specific event that may last for hours or days such as thunderstorms, snowstorms, and the current temperatures [١, p١].

The amount and pattern of rainfalls are considered to be among the most important characteristics of weather that immensely affect agriculture. Nevertheless, it has a direct impact on the water balance in soil for it is interrelated with other weather variables such as solar radiation, humidity, and temperature. Still, both are regarded as primary factors that affect corps growth, diseases, pests, and weeds [٢, p.٣٦٣].

Climate change is causing changes in the weather and rainfall patterns, leading to heat waves, water scarcity, crop failures, floods, droughts, and disease. Understanding these emerging events helps us adapt to the onset of a dynamic climate [,٣ p٨٦].

Changes in rainfall affect agriculture and water resources. To reduce dependence on rainfall, careful land and water management planning is essential. Understanding rainfall trends helps support crops with supplemental water during critical periods. Analyzing rainfall trends will determine whether climatic values are increasing or decreasing, helping to assess the impacts of climate change [,٤p٩٥٢].

To know the exact the amount of rainfall for a specific period of time, the general trend of the rainfall amounts has been noted, and both the changes and deviations of these amounts have been registered (from ١٩٣٧ till ٢٠١٨) by dividing this period into (٧) climate circles in which each circle lasted for (١١) years.

Research Limitation

The place in which the study is conducted lies between (١٤ – ٣٢) degree north latitude and (١٤ – ٤٤) east longitude and the altitude of (٣١,٧ m) [٥].

Data and Method

This study has relied on its data on the amount of rainfall during the rainy season extended from September to May, with the exception of mountainous regions which extended till June.

The study has adopted the analytical approach by describing and interpreting the statistical and climatic data of rainfall amounts in Baghdad over (٨١) years (See Table ١). The 'Cumulative Deviation' approach has been used here to accomplish that instead of the old 'Moving Average' approach in which we usually suffer from losing data at both the beginning and end of the studied period of time.

Nevertheless, the researcher faced a number of difficulties while collecting data of which are the lack of some climatic data issued by the Iraqi Meteorological Organization and Seismology especially those concerning rains in February, March, April, and May (١٩٩١), and in January, February, March, April and May (٢٠٠٣). In addition to the months September, October and November (٢٠٠٤ – ٢٠٠٥).

Rainfall Characteristics

One of the most distinguished characteristics is the rainfall variability especially those of mid-latitude. This happens due to some factors such as the nature of the gaseous atmosphere general circulation, zonal circulation, and the constant shifting of pressure zones.

Table (١), which contains the rainfall annual sum in Baghdad, shows that rainfall amounts vary throughout the determined period of time. It reached its highest level in the year (١٩٧٣-١٩٧٤) with a record of (٣٠٧,٧ mm). It is to be noted that the whole data in this table was collected and

arranged by the researcher from unpublished records of the Water Resources Section at the Iraqi Meteorological Organization and Seismology [٦].

Table ١. The recorded rainfall amounts in Baghdad ١٩٣٧ - ٢٠١٨.

YEAR	The annual rainfall amounts in mm
١٩٣٨-١٩٣٧	٢٤١,٨
١٩٣٩	٢٣٦,٢
١٩٤٠	١٤٤,٩
١٩٤١	١٠٧,٧
١٩٤٢	٧٥,٦
١٩٤٣	١٢٧,٠
١٩٤٤	٦١,٧
١٩٤٥	١٤٠,٠
١٩٤٦	١٧٨,٩
١٩٤٧	١٢٢,٢
١٩٤٨	١١٦,٨
١٩٤٩	١٣٤,١
١٩٥٠	١٣٤,٢
١٩٥١	٢٢٠,٠
١٩٥٢	١٠٦,٦
١٩٥٣	٧٩,٠
١٩٥٤	١٨٩,١
١٩٥٥	٢٥٣,١
١٩٥٦	١٢٦,٩
١٩٥٧	٢٢٨,٥
١٩٥٨	١٩٨,٣
١٩٥٩	١٨١,٤
١٩٦٠	٨٤,١
١٩٦١	٢٠٠,١
١٩٦٢	١٧١,٧
١٩٦٣	١٧٣,٦
١٩٦٤	٨١,٧
١٩٦٥	١٣٣,٨
١٩٦٦	١٢٨,٤
١٩٦٧	١١٥,٦
١٩٦٨	٢٥١,٦
١٩٦٩	١٢٢,٩
١٩٧٠	١٦٣,٧
١٩٧١	١٥٥,٣
١٩٧٢	٢٠٥,٠
١٩٧٣	٦٣,٠
١٩٧٤	٣٠٧,٧
١٩٧٥	١٩٨,٣
١٩٧٦	١٢٧,٥
١٩٧٧	٨٧,٤

١٩٧٨	١٢٧,٢
١٩٧٩	١٢٠,٨
١٩٨٠	٩١,٧
١٩٨١	١٤٤,١
١٩٨٢	١٥١,٣
١٩٨٣	٧٣,٨
١٩٨٤	٨٣,٢
١٩٨٥	١٠٩,٦
١٩٨٦	١٧٠,٠
١٩٨٧	٣٥,٤
١٩٨٨	١٦٤,١
١٩٨٩	١٣٩,٣
١٩٩٠	١٤٠,٨
١٩٩١	٦٥,٨
١٩٩٢	٧١,٥
١٩٩٣	٢٢٠,٣
١٩٩٤	٨٩,٣
١٩٩٥	١٥٧,٢
١٩٩٦	١١٠,١
١٩٩٧	٣٦,٦
١٩٩٨	١٧٣,١
١٩٩٩	٥٥,٨
٢٠٠٠	٦٢,٤
٢٠٠١	١٠٦,٩
٢٠٠٢	٨٤,٣
٢٠٠٣	٢٤,٤
٢٠٠٤	
٢٠٠٥	١١٠,٤
٢٠٠٦	١٤١,٤
٢٠٠٧	١٢٥,٩
٢٠٠٨	٣٧,٦
٢٠٠٩	٥٢,٢
٢٠١٠	٩٦,٨
٢٠١١	١٢١,١
٢٠١٢	٢٩,٣
٢٠١٣	٢٦٣,٦
٢٠١٤	٢٧٨,١
٢٠١٥	٧٣,٢
٢٠١٦	٢١٩,٤
٢٠١٧	١٠٠,٥
٢٠١٨	١٨٣,٢
The Total Rainfall Average	١٣٥,٢

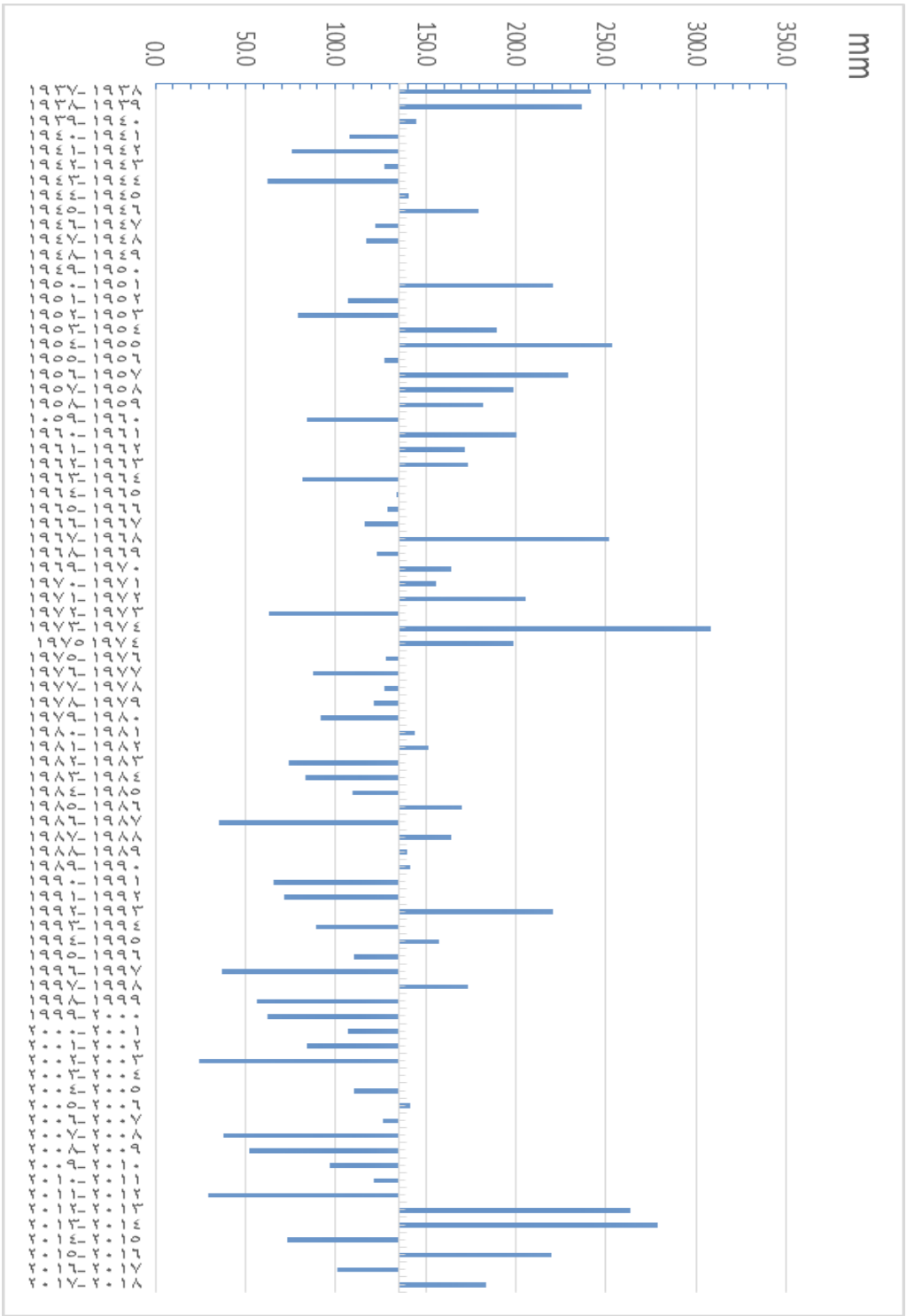
*: Any empty slot refers to missing data.

Chart (١) illustrates a state of divergence and contraposition away from the general average of the annual rainfall amounts, mainly during specific years. These years display either dryness or humidity, and even within it

the amounts distinguishingly varied. The years in which the amount of rain exceeded the general average are (٣٧) years, and those in which it was lower than the general average are (٤٣) years. This 'chart' is done by the researcher depending on the data in Table (١).[٦].

Chart (١)

The Fluctuation of the Annual Rainfall Amounts in Baghdad



Annual Rainfall Trends

A 'Trend' is one of the characteristics that appear in a timeline and which indicates a decrease or increase in the values of that timeline for one or more years. It also refers to climate change if it continues for a specific period of time.

The study adopted an approach to determine the 'General Trend' of rainfalls in Iraq; this method is known as " Cumulative Deviation".

The Cumulative Deviation Approach

Cumulative variances are calculated by the subtraction of monthly or annual values of climate phenomena from the overall average of the timeline values, then adding each variant to the one after it till the end of the timeline values.

In Table (٢), of the cumulative values, the negative values point out the lack of rain, while the positive values refer to the abundance of rain.

In Chart (٢), the results show clearly that all the cumulative values were positive from (١٩٣٧) to (٢٠٠٣). Then from (٢٠٠٤) till (٢٠١٨) it all changed to negative, which indicates sever lack of rain compared with the previous period.

In general, Baghdad witnessed an abundant rainy period extended from (١٩٦٠) to (١٩٩٩). However, it witnessed a rainfall decrease in the following years.

Table (٢)
Variances Accumulation of the Annual Rainfall Values

YEAR	Variances Accumulation
١٩٣٨-١٩٣٧	١٠٦,٦
١٩٣٩	٢٠٧,٦
١٩٤٠	٢١٧,٣
١٩٤١	١٨٩,٨
١٩٤٢	١٣٠,٢
١٩٤٣	١٢٢,٠
١٩٤٤	٤٨,٥
١٩٤٥	٥٣,٣
١٩٤٦	٩٧,٠
١٩٤٧	٨٤,٠
١٩٤٨	٦٥,٦
١٩٤٩	٦٤,٥
١٩٥٠	٦٣,٥
١٩٥١	١٤٨,٣
١٩٥٢	١١٩,٧

١٩٥٣	٦٣,٥
١٩٥٤	١١٧,٤
١٩٥٥	٢٣٥,٣
١٩٥٦	٢٢٧,٠
١٩٥٧	٣٢٠,٣
١٩٥٨	٣٨٣,٤
١٩٥٩	٤٢٩,٦
١٩٦٠	٣٧٨,٥
١٩٦١	٤٤٣,٤
١٩٦٢	٤٧٩,٩
١٩٦٣	٥١٨,٣
١٩٦٤	٤٦٤,٨
١٩٦٥	٤٦٣,٤
١٩٦٦	٤٥٦,٦
١٩٦٧	٤٣٧,٠
١٩٦٨	٥٥٣,٤
١٩٦٩	٥٤١,١
١٩٧٠	٥٦٩,٦
١٩٧١	٥٨٩,٧
١٩٧٢	٦٥٩,٥
١٩٧٣	٥٨٧,٣
١٩٧٤	٧٥٩,٨
١٩٧٥	٨٢٢,٩
١٩٧٦	٨١٥,٢
١٩٧٧	٧٦٧,٤
١٩٧٨	٧٥٩,٤
١٩٧٩	٧٤٥,٠
١٩٨٠	٧٠١,٥
١٩٨١	٧١٠,٤
١٩٨٢	٧٢٦,٥
١٩٨٣	٦٦٥,١
١٩٨٤	٦١٣,١
١٩٨٥	٥٨٧,٥
١٩٨٦	٦٢٢,٣
١٩٨٧	٥٢٢,٥
١٩٨٨	٥٥١,٤
١٩٨٩	٥٥٥,٥
١٩٩٠	٥٦١,٢
١٩٩١	٤٩١,٨
١٩٩٢	٤٢٨,١
١٩٩٣	٥١٣,٢
١٩٩٤	٤٦٧,٣
١٩٩٥	٤٨٩,٣
١٩٩٦	٤٦٤,٢
١٩٩٧	٣٦٥,٦
١٩٩٨	٤٠٣,٥
١٩٩٩	٣٢٤,١
٢٠٠٠	٢٥١,٣
٢٠٠١	٢٢٣,٠
٢٠٠٢	١٧٢,١
٢٠٠٣	٦١,٣
٢٠٠٤	
٢٠٠٥	-٢٤,٨
٢٠٠٦	-١٨,٦
٢٠٠٧	-٢٧,٩
٢٠٠٨	-١٢٥,٥
٢٠٠٩	-٢٠٨,٥
٢٠١٠	-٢٤٦,٩
٢٠١١	-٢٦١,٠
٢٠١٢	-٣٦٦,٩
٢٠١٣	-٢٣٨,٥
٢٠١٤	-٩٥,٦

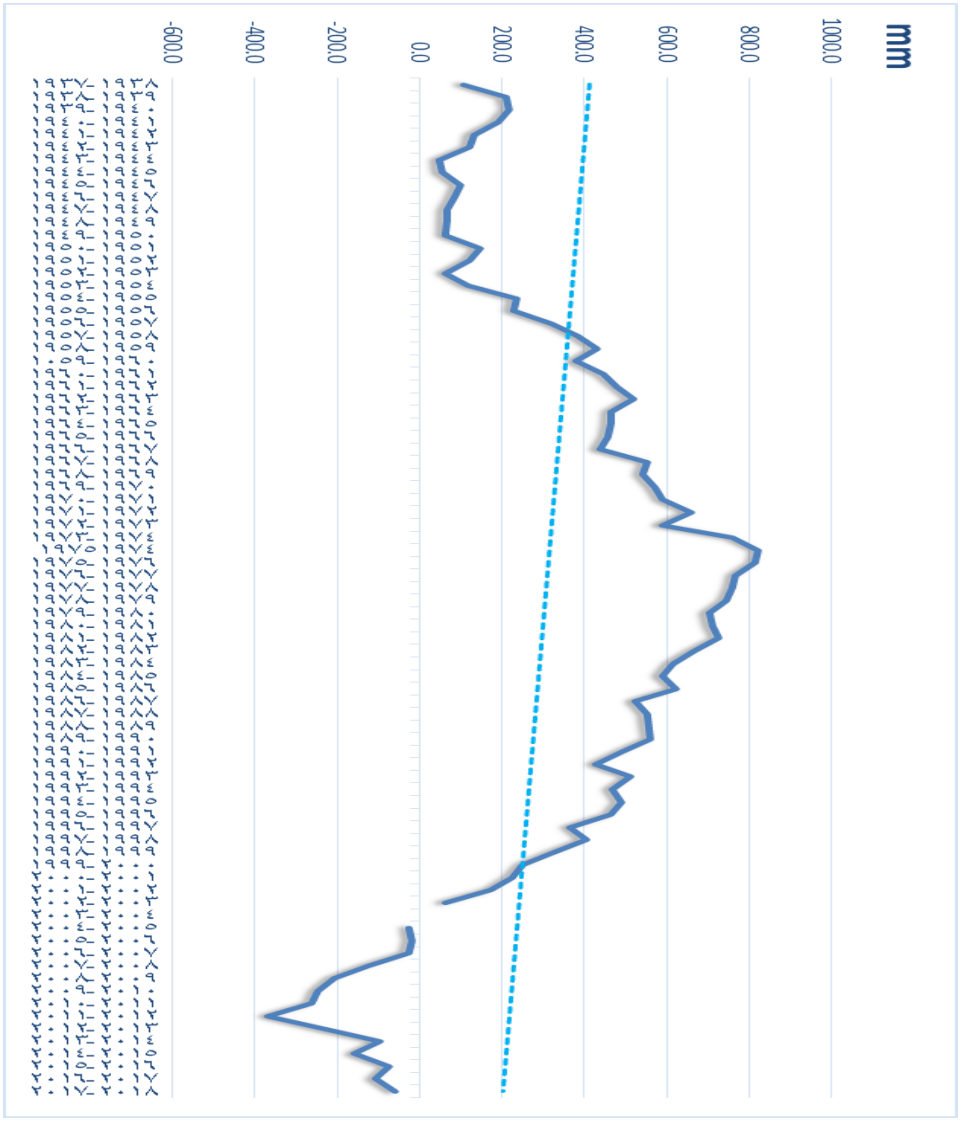
٢٠١٥	-١٥٧,٦
٢٠١٦	-٧٣,٤
٢٠١٧	-١٠٨,١
٢٠١٨	-٦٠,١

*: It is to be noted that the whole data in this table was collected and arranged by the researcher from unpublished records of the Water Resources Section at the Iraqi Meteorological Organization and Seismology [٦].

*: Any empty slot refers to missing data.

Chart (٢)

Cumulative Values of the Annual Rainfall Accumulation in Baghdad



*: This 'chart' is done by the researcher depending on the data in table (٢).[٦].

The Decadal Changes in the Annual Rainfalls of Baghdad

Table (٣) is exhibited to show how much change there is in the rainfall amounts. It illustrates the accumulation average of rain for (١١) years in (٧) climatic cycles.

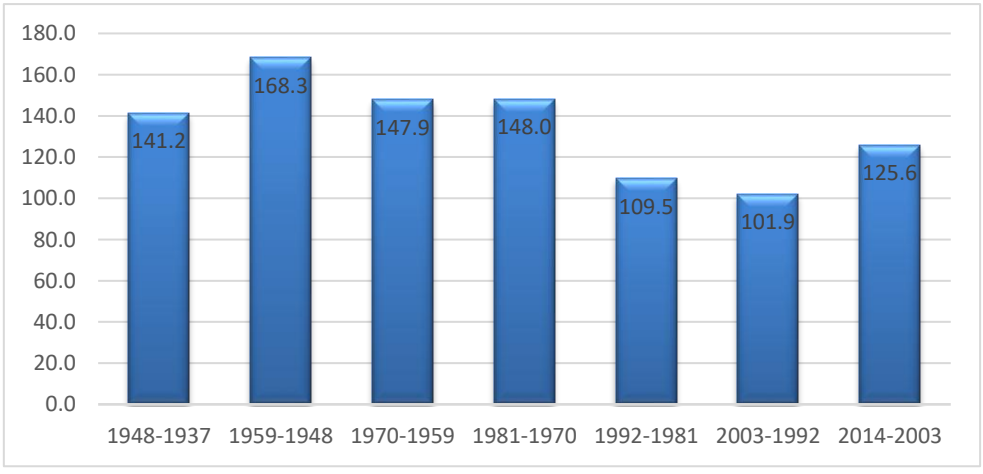
Through the analysis of the data in Table (٣) and the given inputs of Chart (٣), It becomes clear that there was an increase in the rainfall amounts during the seven climatic cycles, especially in the cycle (١٩٤٨-١٩٥٩). The lowest cycle is that of (١٩٩٢-٢٠٠٣).

Table (٣)
The Accumulation Average of Rains for (١١) years in Baghdad

Years	The Accumulation Average
١٩٤٨-١٩٣٧	١٤١,٢
١٩٥٩-١٩٤٨	١٦٨,٣
١٩٧٠-١٩٥٩	١٤٧,٩
١٩٨١-١٩٧٠	١٤٨,٠
١٩٩٢-١٩٨١	١٠٩,٥
٢٠٠٣-١٩٩٢	١٠١,٩
٢٠١٤-٢٠٠٣	١٢٥,٦

*: It is to be noted that the whole data in this table was collected and arranged by the researcher from unpublished records of the Water Resources Section at the Iraqi Meteorological Organization and Seismology.

Chart (٣)
The Accumulation Average of Rains for (١١) years in Baghdad



***: This 'chart' is done by the researcher depending on the data in table (٢).**

The Rainfall Changes that took place over the World

Our climate is experiencing numerous and enormous changes due to the rise of temperature, needless to say, these changes have a huge impact on rainfall patterns, extreme weather, rising sea levels, glaze/ice melting, longer growing seasons, public health, and ecology. These changes are linked to carbon dioxide mounting levels and the greenhouse gases resulting from numerous human activities [١, p.١].

Climatologists have believed, since the ١٩٥٠s, that humans are the reason behind climate change. It has been established that human activities including combustion of fossil fuel, crop cultivation, livestock farming, and deforestation all produce greenhouse emissions. Carbon dioxide amounts in the atmosphere have increased ٤٠٪ than pre-industrialism, and even that is higher than it was ٨٠٠ thousand years ago. The greenhouse gases impact is increased through the reactogenicity resulting from aqueous vapor and this leads to more global warming and climate changing. Natural effects like solar radiation, climatic cycles, and volcanic eruptions cannot fully explain the current warming trend [١, p.٣].

Hydrology was affected in the ١٩٩٠s by climate changes, and the summer of ١٩٩٥ was the driest ever in both England and Wales in which the rain level was even lower than that of ١٩٧٦[٧, p. ٧٨٤,٧٨٥،٧٨٠]. When comparing the annual temperature averages of central England with the rest of the world we can notice an increase in these averages, especially in the years (١٩٦٩-١٩٩٠) and they are warmer than they were ١٠٠ years earlier. The period extended from (٢٠٠٠) to (٢٠٠٩) was the hottest central England ever witnessed [٨, p.٢].

The Arctic (North Pole) temperature is rising faster than any other place on Earth, and that leads to an increase in rainfall levels. This affects the hydrology cycles, energy balance, and sea glacier mass. Rainfall levels

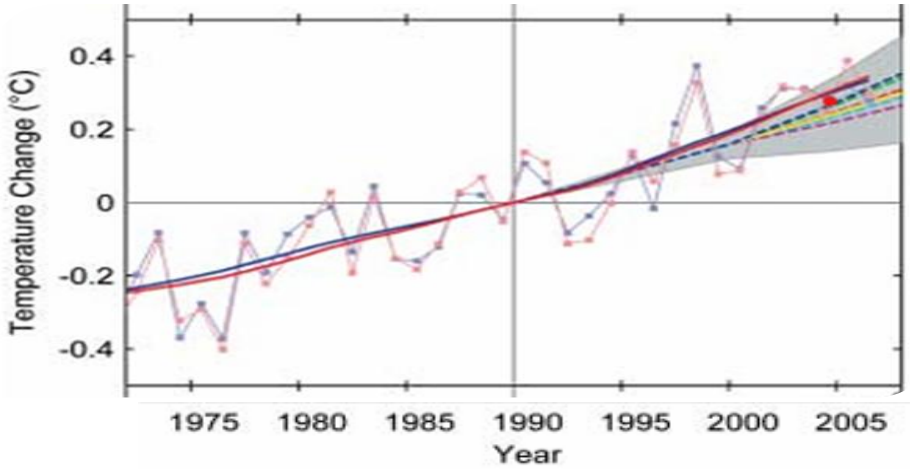
increased in the Arctic from (١٩٨٠) till (٢٠١٦), especially in Autumn, north of the Atlantic Ocean and the surrounding seas [٩]. Global warming has a deep impact on the glaciers in Greenland in which it lost huge amounts of its mass, and this led to a considerable rise in sea levels [١٠, p.١-٣].

The annual rainfall average in Kerala state (India) reveals a slightly descending trend in the long term. It also shows a huge descending in rainfall levels starting from (١٩٥١) upward, with a small decline of ٩,٨٪ from (١٩٩٩) to (٢٠٠٥). A humid period has been noticed starting from (١٩٠٠) up to (١٩٨٠) [١١, p.١٩٤٢].

Chart (٤) presents the changes in global climate parameters since (١٩٣٧) in comparison with IPCC (Intergovernmental Panel on Climate Change) scenarios in Mauna Loa (Hawaii). The data shows a deviation from the trend-line amount in (١٩٩٠) which is the main year for IPCC scenarios [١٢, p.٧٠٩].

Chart (٤)

Changes in Global Climate Parameters since (١٩٣٧) in comparison with IPCC scenarios in Mauna Loa

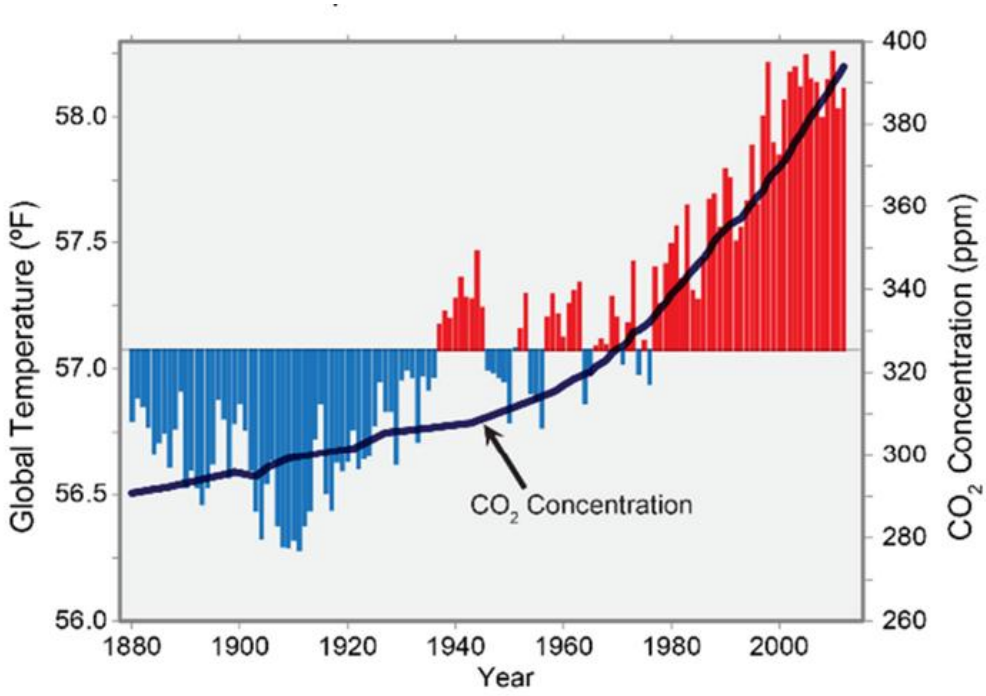


In Chart (٥), the red lines mean global temperature averages on both land or sea is higher than the normal average on the long term, whereas the blue lines mean lower temperatures than the normal averages on the long

term. The black line shows the concentration of carbon dioxide in the atmosphere [١, p٢].

Chart (٥)

Global Temperatures and Carbon Dioxide Concentration



Climate system high temperatures are a fact. Since the ١٩٥٠s enormous unprecedented changes over thousands of years have been recorded. Ocean and atmosphere temperatures have increased, glacier levels have reduced, sea levels have increased, and greenhouse gases have become more concentrated and intensified.

These high temperatures already affect Hawaii and the Pacific Ocean Islands, this can be seen through the rise of sea levels, ocean acidification, rainfall patterns variability, lower stream flow, and winds and wave patterns irregularity [١٣, p.i].

In summary, Earth's temperatures are rising extremely and this has and will lead to countless unprecedented climate changes, according to the fifth evaluation report presented by the Intergovernmental Panel on Climate Change (IPCC).

Conclusions

Based on the obtained results, the rainfall amounts in Baghdad witnessed a clear fluctuation from the normal averages and a substantial decrease in the trend of these amounts and the climatic cycle (١٩٤٨-١٩٥٩) is considered the highest cycle in rainfall amounts. In addition, the lower rains average over the climatic cycle (١٩٩٢-٢٠٠٣) was due to the increasing levels of carbon dioxide. Finally, Hydrology was affected, in the ١٩٩٠s, by climate variability which took place all over the world as a result of rising temperatures. This has a deep impact on climate cycles and is the reason behind changing rainfall trends, extreme weather, sea levels rising, glaciers melting, and growing season disparity; not to mention the effects on the infrastructure, public health, and ecology.

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