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Dynamical Analysis of Severe Rain Events over Iraq

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Abstract

The patterns of rainfall have changed because of the changes in the Earth's climate. Many areas have suffered from lack of water resources. So, increased the studies about to rainfall. The mean annual rainfall is 225.84mm and rainfall fluctuates around it, the trend of rainfall was decreasing for period (1983-2017). The highest amount for mean of monthly rainfall is less than40 mm. The histograms of monthly rain shows the highest counts of (40-50)mm, (30-40)mm,...etc. Using TRMM daily rainfall maps to study the dynamical analysis of severe rainfall cases was conducted in Iraq for four individual study cases. The highest values ranged (80-160)mm. Eleven meteorological elements selected to study their behavior in the process of severe rainfall as (1000-500)mb thickness, mean sea level pressure, 850hPa (relative humidity, temperature and streamlines), 500hPa (vorticity), jet stream at 200hPa, Convective Available Potential Energy (CAPE) and the Total Cloud Water Vapor (TCWV) founding some results that were illustrated in this paper.

Keywords: Rainfall, Meteorological elements, Dynamical analysis, Period.

الخلاصة

تغيرت أنماط هطول الأمطار بسبب التغيرات في مناخ الأرض حيث عانت العديد من المناطق من نقص الموارد المائية. لذلك ازدادت الدراسات عليها. اظهرت النتائج ان معدل هطول الأمطار السنوي هو(٢٢٥,٨٤)ملم ، وان اتجاه هطول الأمطار يتناقص للفترة (١٩٨٣-٢٠١٧). أعلى كمية لمعدل الامطار الشهري ٣٦ملم. أعلى تعدادات الأمطار الشهرية للكميات (٤٠-٥٠)ملم و (٣٠-٤٠)ملم و (٢٠-٣٠)ملم. و باستخدام الخرائط اليومية لهطول الأمطار(TRMM) تمت دراسة التحليل الديناميكي لأربعة حالات امطار غزيرة حدثت فوق العراق. أعلى كميات امطار للحالات الاربع(٨٠-١٦٠)ملم. لدراسة سلوك(١١(عنصر التي ادت الى الامطار الغزي. كالسمك بين طبقتي (١٠٠٠-٥٠٠) هكتوباسكال و متوسط ضغط مستوى البحر) MSL) والرطوبة النسبية و درجة الحرارة وخطوط انسياب الرياح على ارتفاع ٨٥٠ هكتوباسكال والحركة الدردورية في طبقة ٥٠٠هكتوباسكال و التيار النفاث في طبقة ٢٠٠هكتوباسكال, الطاقة الجهدية الحملية الفعالة (CAPE) و مجموع عمود بخار الماء (TCWV) التي أسفرت عن بعض النتائج التي تم توضيحها في هذه الدراسة.

Introduction

Rain is one of the main sources of water availability in nature and thus affects the lives of all creatures. Rainfall amounts vary from region to region depending on where they are located on Earth. It is very important to know quantity of rainfall for many purposes, like agriculture and water resources. Rain has an active role in the hydrological cycle and improves climate and weather prediction so monitoring rainfall amounts across the globe is very necessary [1]. Rain gauges are only available on land and especially urban areas therefore remote sensing techniques (radars and satellites) in monitoring rainfall provides wide range of observations over land and oceans [2]. Radar, as an active instrument, sends pulses of electromagnetic waves and measures return signal from targets such as raindrops while satellites carry different types of sensors and can cover the entire globe. Availability of rainfall measurements around the globe will lead to a better understanding the hydrological cycle and therefore enhance weather forecasting, climate studies, and climate change monitoring [3]. For these reasons an extensive research works have been conducted using satellite measurements of rainfall [4, 5]. Many distinguished works were carried out over the past two decades.

Bellerby *et al*., (2000) [4] developed a method for estimating rainfall from Tropical Rainfall Measurements Mission (TRMM). Gruber *et al*., (2000) [6] compared satellite estimates of rainfall with those measured by rain gauges for entire globe. Chen (2004) [7] developed an algorithm to estimate instantaneous rainfall from satellite data. Teo (2006) [8] uses satellite rainfall data to predict crop production in Africa. Artan *et al*., (2007) [9] uses satellite estimates of rainfall to predict floods. Recently many workers in Iraq use remotely sensed data of rainfall in their research works. Jamil and Al-Jumaily (2015) [10] investigated the convective rainstorms over Iraq using TRMM measurements. Abdulrida and Al-Jumaily (2016) [11] compared rain gauge monthly rainfall with TRMM-3B42 data and found that the two sets of data were highly correlated. Al-Zuhairi *et al*., (2016) [12] analyzed TRMM precipitation radar data and their findings give a good information on the rain characteristics in Iraq. The aim of this work is to study the dynamical situations of severe rainstorms using data from Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) and National Center for Environmental Prediction (NCEP).

Materials and Methods

Study area

Iraq is located between latitudes of 29°5- to 37°15- N and longitudes of 38°45- to 48° 45-E. Iraq is lies east of the Mediterranean Sea, and north east of the Red Sea. Those two seas are the most sources of moisture for precipitation activities in Iraq. Rainfall is low in central and southern of Iraq (100-200 mm) but it concentrates in northern of Iraq, which reach about 1000 mm, and falls in November to April. Roughly, 90 percent of the annual rainfall occurs between November and April, most of it in the winter months from December through March. The remaining six months, particularly the hottest ones of June, July, and August, are dry. The combination of rain shortage and extreme heat makes much of Iraq a desert [13].

Data Sources

Daily data of rainfall and related meteorological parameters for the period of 1980 to 2017 were used in this work. Meteorological parameters include mean sea level pressure, 850 hPa relative humidity, temperature, and streamlines, 500 hPa vorticity and geopotential height, 200 hPa stream lines and isotachs, Convective Available Potential Energy (CAPE), and low, middle, and, high clouds. Rainfall data were obtained from The Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) Web service [14] and from TRMM. Meteorological parameters were acquired from the European Center for Medium Range Weather Forecasting (ECMWF) for 00Z, 06Z, 12Z, and 18 Z in NetCDF file format [15]. Two freely available software, Grads [16] and Meteo info [17] were used to process and visualize the data.

Results and Discussion

Figures 1 to 3 shows general statistics for rainfall over Iraq for the period of 1983-2017. It is seen that the mean annual rainfall is about 225.84 mm and rainfall fluctuates around this mean. It is notable that before 2007 annual rainfall was above the mean while after 2007 the rainfall was below the mean. The overall trend of rainfall was decreasing.

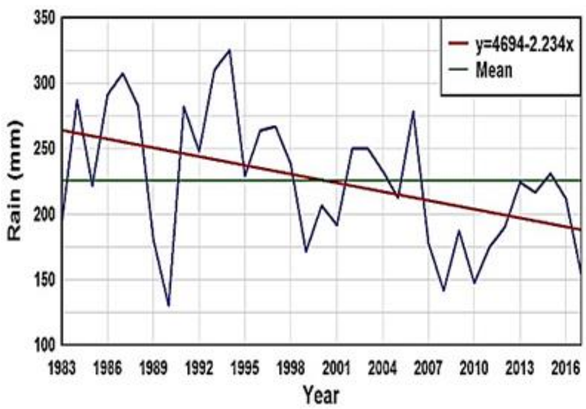

Figure 1: Annual rainfall over Iraq for the period 1983-2017.

Figure (2) shows histograms of monthly rain occurrence. It is clear that highest counts of the month of January are those of (40-50) mm interval and highest counts during the months of February and March are those of (20-30) mm. During April and May the highest counts come from rain intervals of (10-20) and (0-10) mm respectively. During summer months and September counts only come from intervals (0-10) mm, December is of interval (20-30) mm.

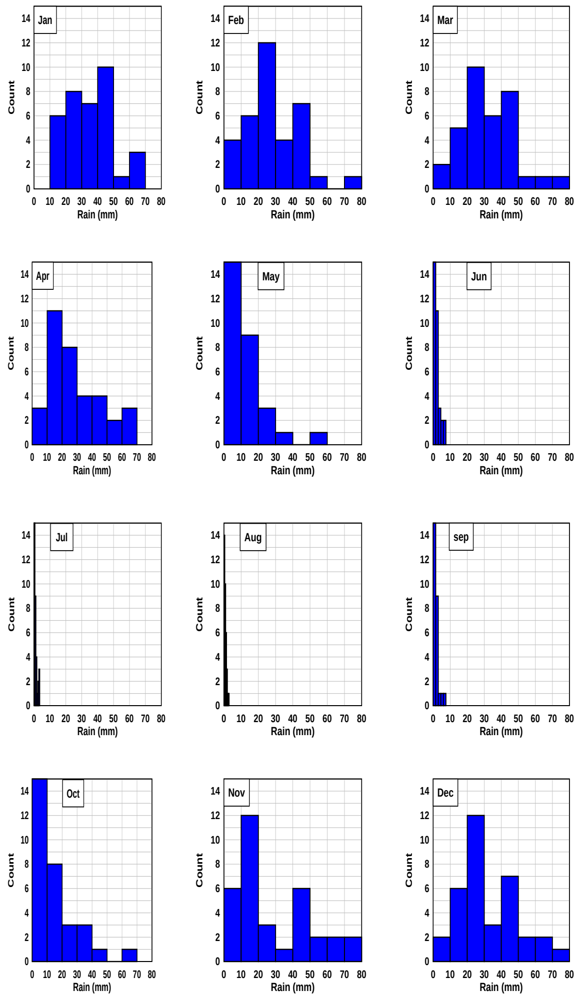

Figure 2 : The monthly rain occurrence over iraq for the period 1983-2017.

The mean of monthly rainfall (Figure 3) indicate that rainiest months are January, February, October, November, and December with a rainfall above 30 mm/month. March is characterized by slightly less than 30 mm/month. The rain values during April and September are comparable and less than 15 mm/month. During the remaining months, which include May and summer months, rainfall is trivial.

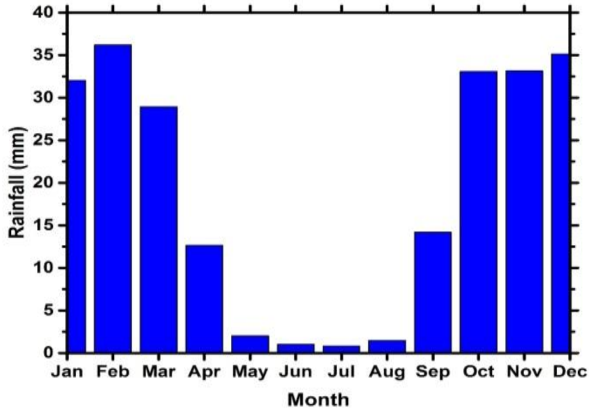

Figure 3: average Monthly rainfall over Iraq for the period 1983-2017.

To study the dynamics of severe rainstorms over Iraq many case studies were analyzed. In this paper, four of these cases are discussed. Figure (4) shows TRMM daily rainfall maps for the four cases: 03 Feb 2006, 17 Nov 2009, 19 Nov 2013, and 24 Dec 2016. During 03 Feb 2006 the range of daily precipitation over Iraq was from 20mm to over140mm, the highest values are concentrated along the eastward boundary of Iraq at 160 mm and small areas in middle of Iraq, another spots of rainfall ranged about 100mm and 80mm at different places. During 17 November 2009 the amount of rainfall during 24h concentrated at zones, one at northwest in Syria near The Iraqi-Syrian border, the maximum amount was (80-90)mm. two other zones within the Iraqi border one at north and others at south its quantity ranged about (10-30)mm increases to be the maximum amount (30-40)mm. Other place at northwest of Iraq about maximum amount exceeded of 100mm. (the biggest zone at northeast of Iraq about maximum amount exceeded of 100mm). During 19 Nov 2013 the locations of rainfall were in the middle and south of Iraq, the maximum amount concentrated on middle of Iraq about (90-100) mm, there were another centers in the south and east border but their amounts was (60-70)mm. the rest places their rainfall amounts were less than that. During 24 Dec 2016 the precipitation above middle region of Iraq and from north along the east boundary except the southeast toward of Iraq. The range of daily precipitation about (10 to 90) mm, the highest values are concentrated in the northeast and middle region of Iraq about (80-90) mm.

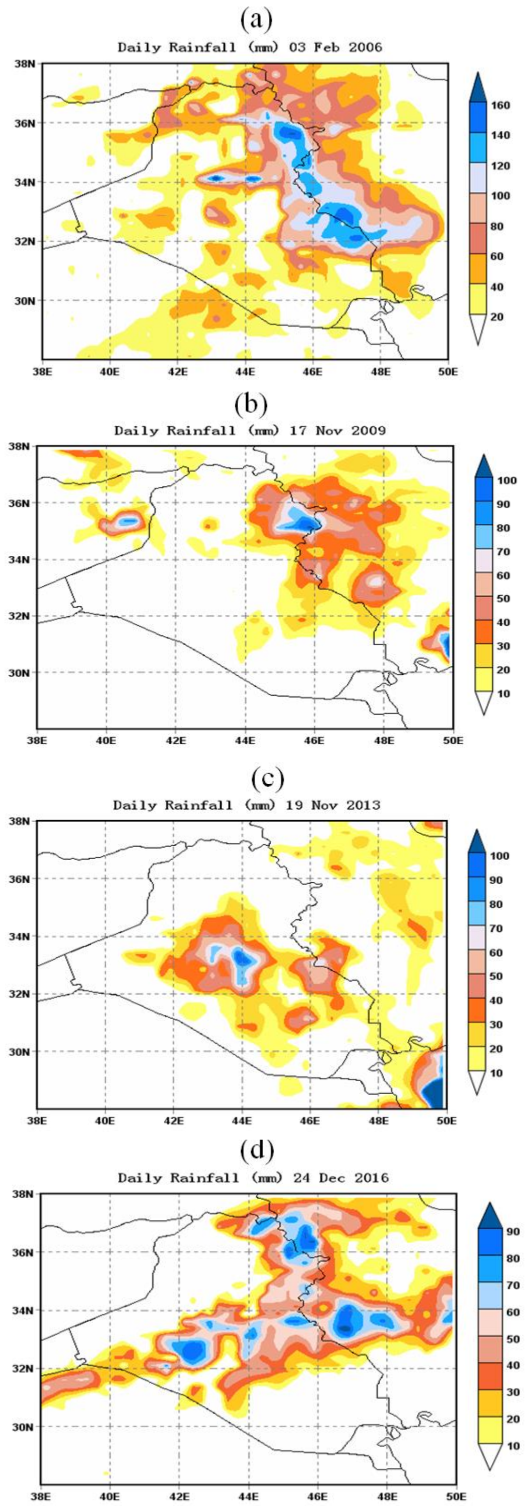

Figure 4: Daily rainfall for heavy storm over Iraq on a) 03 Feb 2006, b) 17 Nov 2009, c) 19 Nov 2013, and d) 24 Dec 2016.

Figure 5 gives the 1000-500 mb thickness and mean sea level pressure map for the five cases. Low-pressure system from Red Sea exists all cases, but its strength different from case to another depends on the strength of high-pressure system that exists at north. The thickness layer ranged. In one case only (24 Dec 2016) there is progression for warm air mass, the others the cold air mass advanced. The thickness layer (1000-500)mb about (560 to 555) dam. Only during the case, 03 Feb 2006 the contours of mean sea level pressure are ranged 1004 mb. The others about 1019 mb. Figure 6 shows the 850 hPa relative humidity, temperature and streamlines maps for the case studies. Most of the cases are with higher values of relative humidity concentrated at north and west of Iraq ranged (80-90)% only case (19 11 2013) its relative humidity ranged (60-70)%, three of them fed from Mediterranean Sea and Red Sea and the other one (17 Nov 2009) weakly fed from Red Sea. At some cases, the streamlines move a spiral motion from northwest toward east. There is homogeneity in temperature decline (<1 ºC). Figure 7 illustrates the 500 hPa vorticity and geopotential height maps for the case studies. Advection of positive relative vorticity with varies intensities increase gradually (from 4 to>10) 1e5/s is associated with Progression of trough at 500mb level. The geopotential height is decreased synchronous with progresses of trough at 500mb level. That is mean cold air mass over the area. Figure 8 shows the 200 hPa streamlines and isotaches maps. The case of (19 NOV 2013), jet stream cross Iraqi areas nearly straight and makes the trough at 500mb cross faster than other cases. At other cases jet stream flow as curved shape so orientated the trajectory of trough at upper levels (500mb) and make its speed slower then blocked it. All cases with speed range (40-60) m/s decrease toward north. Figure 9 presents the CAPE and the (TCWV) maps for the four storms. The feeding of cases in general was from Red Sea and an Arabian Gulf. The values varies from case to another range (200-1200)J/Kg. The (TCWV) shows different values; the maximum value was (30mm).

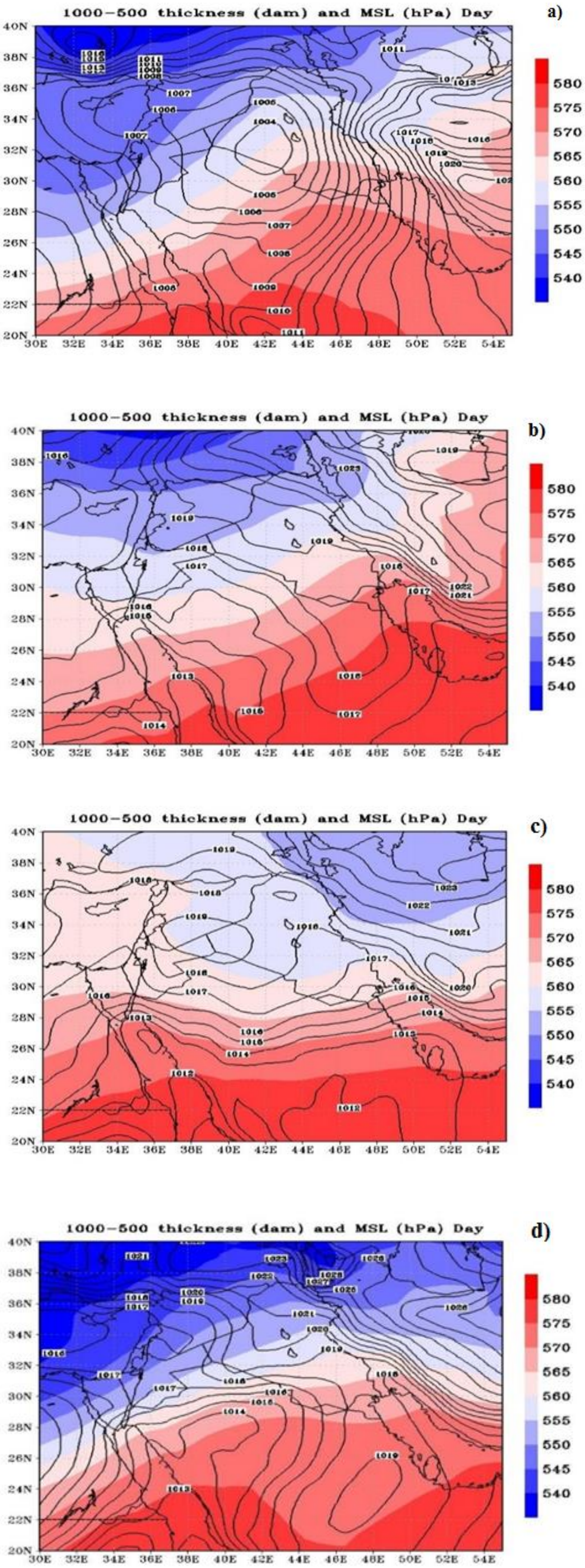

Figure 5: (1000-500) mb thickness and MSL for: a) 03 Feb 2006, b) 17 Nov 2009, c) 19 Nov 2013, and d) 24 Dec 2016.

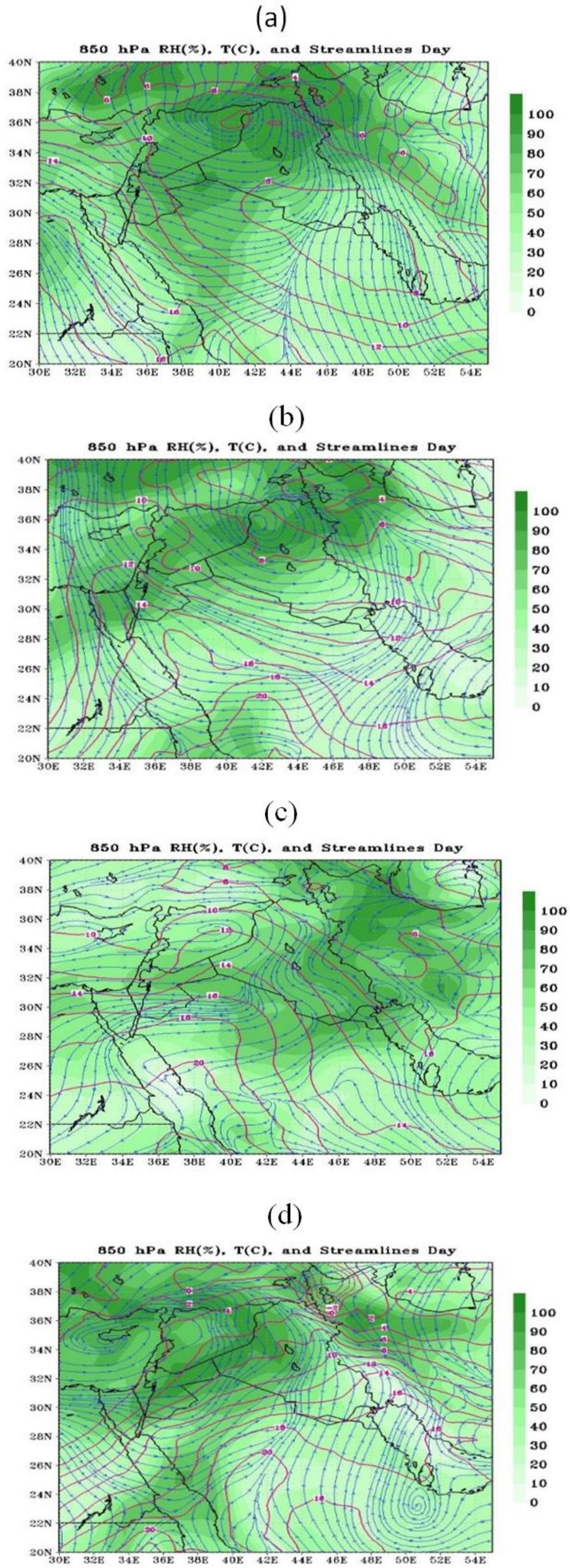

Figure 6: Relative humidity, temperature and streamlines for: a) 03 Feb 2006, b) 17 Nov 2009, c) 19 Nov 2013, and d) 24 Dec 2016.

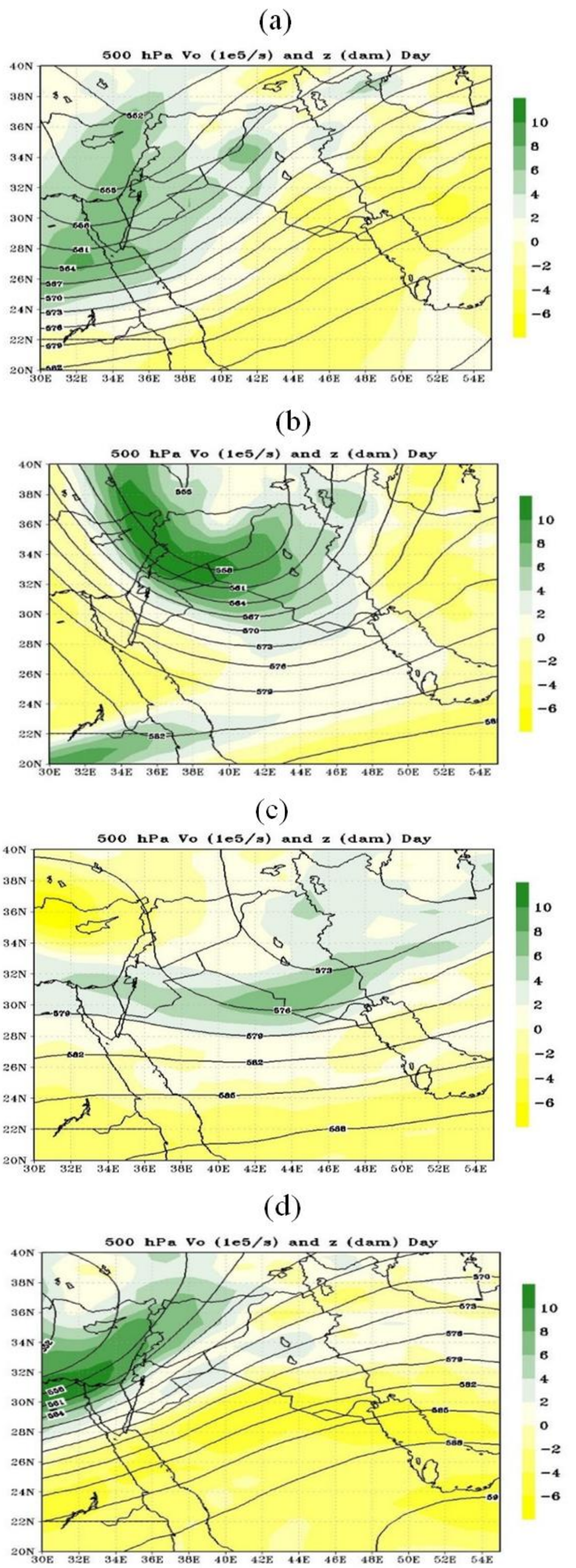

Figure 7: 500 hP a vorticity and geopotentail height for a) 03 Feb 2006, b) 17 Nov 2009, c) 19 Nov 2013, and d) 24 Dec 2016.

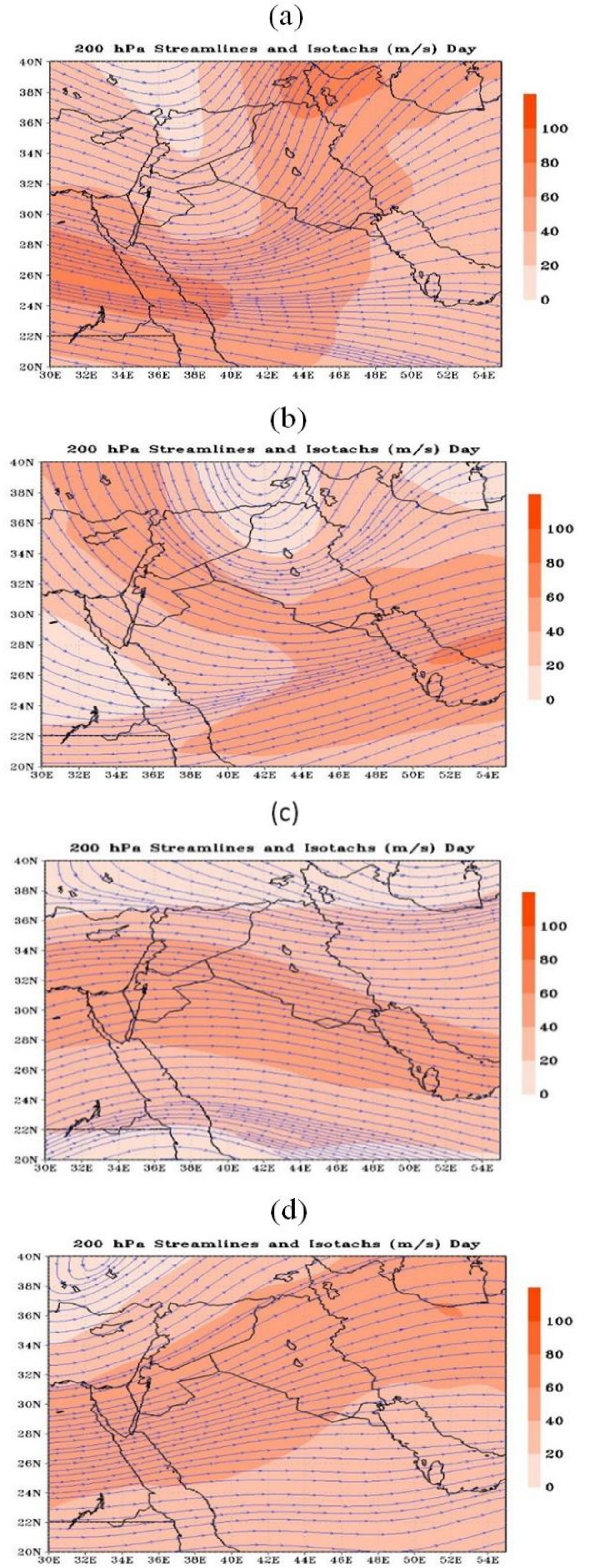

Figure 8: 200 hP a streamlines and isotaches height for a) 03 Feb 2006, b) 17 Nov 2009, c) 19 Nov 2013, and d) 24 Dec 2016.

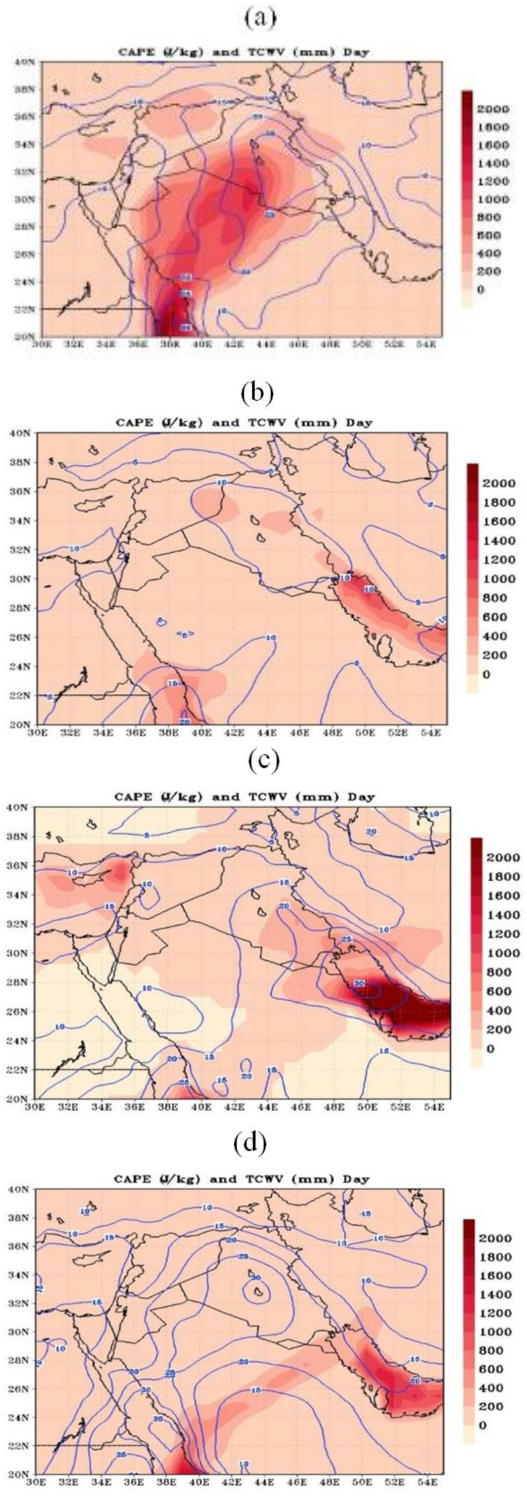

Figure 9: CAPE and total cloud water vapor for a) 03 Feb 2006, b) 17 Nov 2009, c) 19 Nov 2013, and d) 24 Dec 2016.

Finally, figure (10) gives the high, middle, and low cloud covers maps for the four case studies. There were high clouds over most cases with amount ranged (0.4 to 1.0) frac.

Differ only one case (19 Nov 2013) hasn't any amount. The amount of medium cloud is covered about (0.2 to 0 .4) frac at different places of Iraq. The low cloud exists at different places of Iraq.

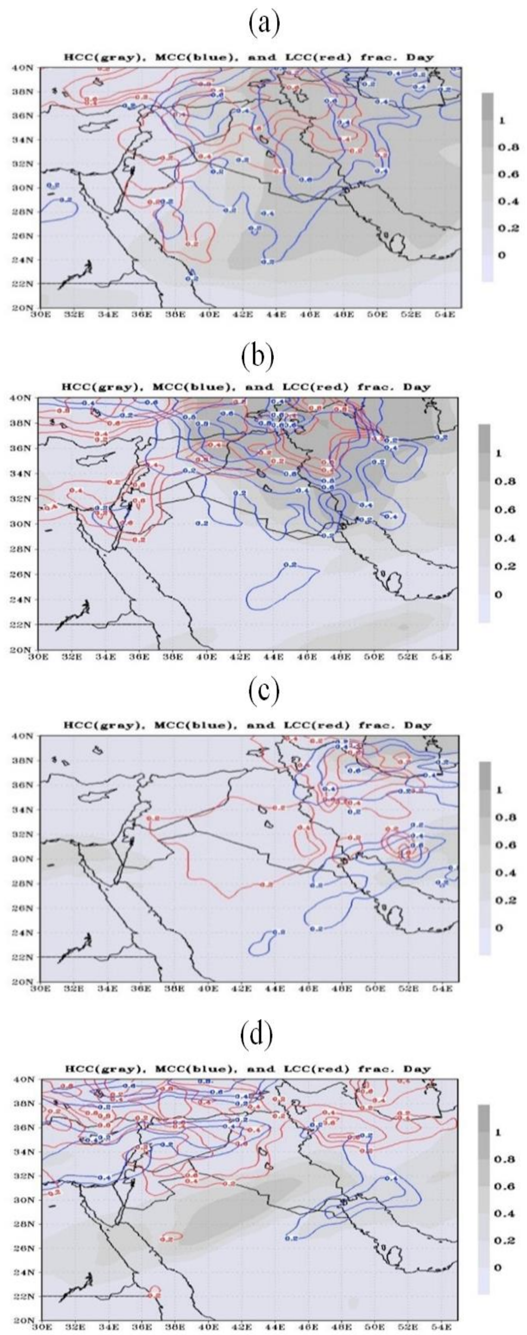

Figure 10: High, middle, and low clouds Covers for a) 03 Feb 2006, b)17 Nov2009 c) 19 Nov 2013, and d) 24 Dec 2016.

Conclusions

In this study, four cases of severe rain events and related atmospheric parameters were analyzed for the period (1983–2016), the analysis included two parts. The first one includes some statistical indicators for annual and monthly rainfall. The second one is the dynamical analysis for severe rainfall cases. The most important conclusions reached in this research: The mean annual rainfall is about 225.84 mm. The overall trend of rainfall was decreasing. The monthly rainfall indicates that a rainiest month is February with a rainfall amount above 35mm/month, while other months are less than that. The counts of different intervals for rainfall every month are varying from month to month. During summer months and September counts only come from intervals (0-10). The maximum amount of daily rainfall for the four cases ranged between (80-160)mm. Low-pressure system from Red Sea exists at all cases. Most cases has: thickness layer ranged (560 to555) dam with cold air mass advanced, the contours (MSL) pressure are ranged 1019mb, the higher values of (RH) are ranged between(80-90)%, the streamlines move a spiral motion, there is homogeneity in temperature decline (<1 ºC), (PVA) increase gradually (from 4 to >10) 1e5/s and cold air mass at 500hpa layer, jet stream orientated the trajectory of trough at upper levels (500mb), and make its speed slower, then blocked it, all cases the jet stream's speed is ranged (40-60) m/s, the (CAPE) value ranged (200-1200)J/Kg, and the maximum value of (TCWV) was (30mm). Finally, the high, middle, and low cloud exists at all cases except the case (19 Nov 2013) hasn't any amount of high cloud.

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