

# Evaluation of Atmospheric Blocking Effects on Weather Events in Iraq

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## ABSTRACT

Atmospheric blocking has received a lot of attention in recent years due to its impacts on mid-latitude circulation and then on weather extremes such as cold spells, heat waves, drought, and heavy rain. In this paper, the effects of atmospheric blocking on weather events "rainfall in particular" over Iraq are evaluated. Daily meteorological data from the National Centers for Environmental Prediction (NCEP) for the period 2002-2018 were analyzed to identify different atmospheric blocking systems over Iraq and surrounded regions. In order to locate the blocks on maps, the study domain is extended from 10-70° N and 10-70° E for mean sea level pressure. This study state two cases of Omega blocking system occurred on 25 Jan 2006 and 01-03 Feb 2006. Rainfall observed by the Tropical Rainfall Measurements Mission (TRMM) along with true color cloud images detected by the Moderate Resolution Imaging Spectroradiometer (MODIS) were employed for determining the severity and trajectory of rainstorms associated with atmospheric blocking systems. NCEP provides data with a spatial resolution of  $2.5^\circ \times 2.5^\circ$  while TRMM is  $0.25^\circ \times 0.25^\circ$ . Analysis of one typical year (2016) showed that among 24 blocking systems detected during the period of this work, 37.5% were Omega blocks, 20.8% were Cut-off low blocks, 16.7% were Rex blocks, and the percentage of the Cut-off high and Split flow blocks were 12.5% each. The results also indicated that the strongest blocking was the Omega blocking that occurred on 01-03 Feb 2006 and resulted in 120 mm rainfall.

**KEYWORDS:** Atmospheric blocking, Omega block, Heavy precipitation, Iraq.

## الخلاصة

تحتل الاعاقة الجوية بالكثير من الاهتمام في السنوات الأخيرة نظرًا لتأثيرها على الدورة الجوية في منطقة العروض الوسطى ومن ثم على الظواهر الجوية القاسية مثل نوبات البرد وموجات الحرارة والجفاف والأمطار الغزيرة. في هذا البحث، يتم تقييم تأثير الاعاقة الجوية على أحداث الطقس "هطول الأمطار بشكل خاص" على العراق. وقد تم تحليل بيانات الأرصاد الجوية اليومية من المراكز الوطنية للتنبؤ البيئي (NCEP) للفترة 2002-2018 لتحديد أنظمة الاعاقة الجوية المختلفة على العراق والمناطق المحيطة. من أجل تحديد موقع أنظمة الاعاقة على الخرائط، فإن مجال الدراسة يمتد من 10 إلى 70 درجة شمالاً و 10 إلى 70 درجة شرقاً لمعدل الضغط عند مستوى سطح البحر. هذه الدراسة توضح حالتين من نظام القطع من نوع أوميغا حدثت في 25 يناير 2006 و 01-03 فبراير 2006. تم استخدام هطول الأمطار المرصود بواسطة مهمة قياسات الأمطار الاستوائية (TRMM) إلى جانب صور صور ملونة حقيقة للغيوم التي تم الحصول عليها بواسطة مقياس الطيف الضوئي للتصوير متوسط الدقة (MODIS) لتحديد شدة ومسار العواصف الممطرة المرتبطة بأنظمة الاعاقة الجوية. يوفر NCEP البيانات بدقة مكانية  $2.5^\circ \times 2.5^\circ$  بينما TRMM هو  $0.25^\circ \times 0.25^\circ$ . أظهر التحليل لسنة نموذجية واحدة (2016) أنه من بين 24 حالة اعاقة تم اكتشافها خلال فترة هذا العمل، كانت 37.5% اعاقة أوميغا، 20.8% اعاقة القطع المنخفض، و 16.7% كانت اعاقة ريكس، والنسبة المئوية لاعاقة القطع العالي و تدفق الانقسام 12.5% لكل منهما. أشارت النتائج أيضًا إلى أن أقوى اعاقة كانت اعاقة أوميغا الذي حدث في الفترة 01-03 فبراير 2006 ونتج عنها هطول الأمطار بمقدار 120 ملم.

## INTRODUCTION

The blocking term in weather is a term used to indicate atmospheric pressure large scale patterns that are not moving, and they are nearly stationary. At the occurrence of blocking, the weather conditions remain for a long period of

time (several days to even weeks). This can cause extreme weather events that can lead to flood, drought, heavy rain, high temperatures, low temperatures, and other weather hazards. Atmospheric blocking is one of the most dramatic phenomena of large-scale circulation in the

middle troposphere at mid and high latitudes [1] [2]. There are five types of atmospheric blocking are Omega blocks, Rex blocks, Cutoff-high, Split flow and Cutoff-low [3].

#### **- Omega Block**

It resembles the Greek letter Omega and is best analyzed at 500 hPa. The region under the Omega block experiences dry weather and light winds for an extended period of time, while rain and clouds are common in association with the two troughs on either side of the Omega block.

#### **- Rex Block**

A Rex block resembles the letter "S". A Rex block sets up with a strong high-pressure ridge adjacent to a strong low-pressure trough. A large ridge is north of a large trough.

#### **- Cut-off High**

This high-pressure cell can become fixed over the same general region for several days. The air is most stable at the center of the high pressure.

#### **- Cut-Off Low**

Cut-off lows commonly occur when the upper-level winds shift to higher latitude and leave a low-pressure circulating behind. They can persist for several days, bringing several days of rainfall.

#### **- Split Flow**

A Split flow occurs when the jet stream branches into two separate branches. Weather systems flow quickly through each branch of the jet, while the weather pattern becomes stagnant in the region between the two jets.

The aim of this research is to evaluate the effect of atmospheric blocking on weather events over Iraq. The research focuses on severe to extreme rain events for the period 25 Jan 2006 and 01-03 Feb 2006. Azizi and Khalili (2011) found that the intensity and position of the blocking event play an important role in the extreme cold occurrence [4]. Azizi and Khalili (2013) examined the relationship between precipitation anomalies and atmospheric blocking for a region between 60° W to 50° E for a period of 1978– 2007. The results indicated that if a southern trough of dipole blocking places over a region, it will lead to precipitation in a longer period. In addition, the quasi-stationary nature of blocking increases vorticity advection [5]. Masoompour et al. (2014) [3] studied the relationship between omega

blocking and rainfall over Iran by using the Geographic Information Systems (GIS). The results indicate that the existence of a blocking high over the northern portion of the Caspian Sea caused the activity of two accompanying low-pressure systems in which the western low resulted in excessive and intensive rainfall. Rousta et al. (2014) investigated blocking effects on rainfall northwestern Iran. Their results indicate that 65% of blocking systems had a positive effect on the rainfall occurrence, while 35% indicated a negative impact (dry short-spell) over the area [6]. Dong et al. (2018) [7] examined the dynamical relationship of atmospheric blocking over the United State to drought and heat wave. They summarized that atmospheric blocking can reinforce droughts and heat waves during the concurrent period. In addition, Mohr et al. (2019) [8] reported on the relationship between atmospheric blocking and thunderstorm activity over western and central Europe. They indicated that blocking situation is on average associated with weak wind speeds at mid-troposphere levels or weak wind shear.

## **METHODOLOGIES**

### ***Study area and data source***

The study area in this work covers Iraq entirely and surrounded areas with a domain extended from 10-70° N and 10-70° E. Surface and upper level meteorological data from the National Centers for Environmental Prediction (NCEP) [9] are used and they are summarized in Table (1) that lists the meteorological elements obtained for each pressure level. NCEP provides data with a spatial resolution of  $2.5^{\circ} \times 2.5^{\circ}$ .

### ***Proposed Method***

The Grid Analysis and Display System (GrADS) from the Center for Ocean-Land-Atmosphere Studies (COLA), George Mason University, Virginia, USA was used for plotting to analyze the NCEP data. The GrADS system allows plotting more than one map in each single run (animation). GrADS-Script file (gs file) was written to plot 365 (or 366 for leap year) mean sea level pressure maps in one run and then these maps were analyzed to identify the different types of blocking. GrADS also were used to plot maps of the other meteorological variable.

**Table (1).** Meteorological data used in the study.

Pressure level	Elements	Units
Mean sea level	Pressure	hPa
	lifted index	Dimensionless
850 hPa	Temperature	°C
	Relative humidity	%
	Streamline	m/s
700 hPa	Relative humidity	%
	Vertical velocity (omega)	Pa/s
500 hPa	Relative vorticity	m/s
	Geopotential height	dam
300 hPa	Wind components	m/s

## RESULTS AND DISCUSSION

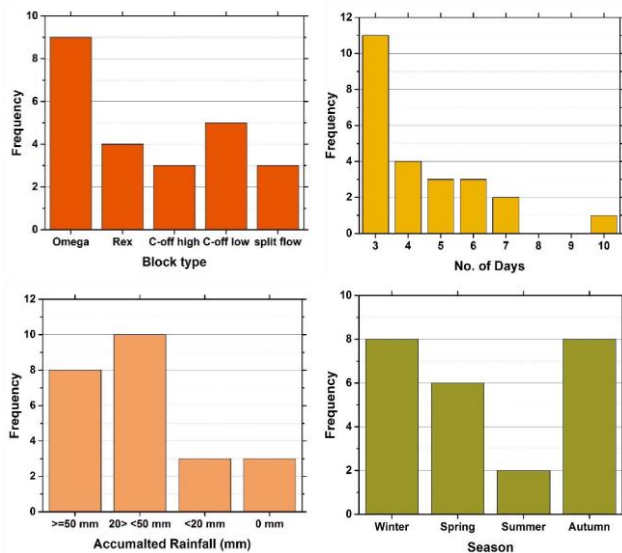
### *Characteristics of Atmospheric Blocking over the Region*

To determine the general characteristics of blocking systems over the region of interest, the year 2016 was chosen as a typical example because it has no missing data and blockings were easier to be identified than those during other more recent years. According to Table (2) that summarizes the analysis results for that year, the five types of blocking were identified with 24 blocking systems. Figure (1) shows some statistics for these results. It is seen that 9 out of 24 blockings were Omega block (37.5%); 4 out of 24 blockings were Rex block (16.7%); 3 out of 24 blockings were Cut-off high blocks (12.5%); 5 out of 24 blockings were Cut-off low (20.8%); The number of Split flow block was like the Cut-off high blocks (12.5%). Most of the blocking lasted 3 days (45.8%) and only one event lasted 10 days. 8 events resulted in rainfall rates of more than 50 mm and 10 events produced rainfall rates between 20 and 50 mm. This means that 75% of blocking systems produced more than 20 mm rain. The results also indicate that most strong blocking was the Omega blocking that occurred on 18-23

February and resulted in 120 mm. Results also indicates that 8 blocking events occurred in winter and in autumn, 6 blocking occurred in spring and only 2 blockings happened in summer.

**Table (2).** Different types of blocking systems observed over the study region during the year 2016.

Blocking Type	Duration (day)	Accumulated Rainfall (mm)
Cutoff-low	7	94
Cutoff-low	3	20
Omega	3	23
Spilt flow	3	13
Omega	6	120
Omega	3	100
Spilt flow	4	61
Omega	3	19
Omega	3	20
Omega	10	55
Rex	3	20
Omega	4	42
Rex	5	31
Cutoff-high	5	24
Cutoff-high	4	0
Omega	6	13
Cutoff-low	6	22
Omega	3	0
Cutoff-low	3	13
Rex	5	21
Cutoff-high	3	82
Rex	7	55
Cutoff-low	4	39
Split flow	3	69



**Figure (1).** Statistical analysis of atmospheric blocking over the region in 2016.

### **Omega Blocking**

Figure (2) shows an example of omega pressure blocking. This blocking occurred on 25 Jan 2006. The pressure patterns dominated over the region is characterized by a center of low pressure with a value of 1008 hPa, located on the eastern part of the Mediterranean Sea, close to Cyprus while the second low pressure is located over Finland with a value of 1012 hPa and the center of high pressure, with a value of 1032 hPa, is located over Kazakhstan, just north of the Caspian Sea.

The lifted index pattern indicates that the weather over the area north of the blocking, i.e. the high pressure area, was very stable while over the area around the low pressure system the weather was unstable. Few thunderstorms were likely occurred over the Red Sea where the lifted index was between 0 and -5 as shown in Figure (2a). The cloud pattern over Iraq and surrounding regions on that day indicates that the entire region was totally covered by clouds except few areas in the northeast, southwest and center of Iraq, while the clouds is covering few areas over Saudi Arabia as shown in Figure (2b). The daily rainfall map in Figure (2c) shows rain falling over central and southeastern Iraq with values below 55 mm / day, the maximum rainfall was 115 mm / day over western Iran. Figure (3) shows upper air weather maps for 850, 700, 500, and 300 hPa levels for 25 Jan 2006. The 850 hPa map indicates that the relative humidity over Iraq was more 80% and about 100% over Turkey. Temperature over Iraq was ranging between 3 °C in the north to 16 °C in the south. The 700 hPa map illustrates that air

over southwestern Iraq was drier than air in the 850 hPa (less 70%). The vertical velocity was negative over the area of interest indicating upward motion. The maximum upward motion was over Syria which was -0.3 Pa/s. The 500 hPa map shows that the lowest geopotential height was 540 dam and was located over Greece. This region of cold air is just above the surface low pressure system. The relative vorticity pattern illustrates that there was strong positive vorticity (about  $10 \times 10^{-5} \text{ s}^{-1}$ ) above the surface low pressure system which means that there was a significant cyclonic rotation in that location which helps to intensify the storm development. The 300 hPa map shows that sub-tropical jet stream was passing over the Mediterranean Sea and North Africa towards Jordan, Syria, and northern parts of Iraq and Iran. The strongest part of the jet with wind speed up to more than 60 m/s was located over the northeastern part of Libya, north of Egypt and the southwest coast of the Mediterranean. The jet was passing just above the surface low pressure system.

### **Torrential Rain Case Study**

#### **February 2006 Case Study**

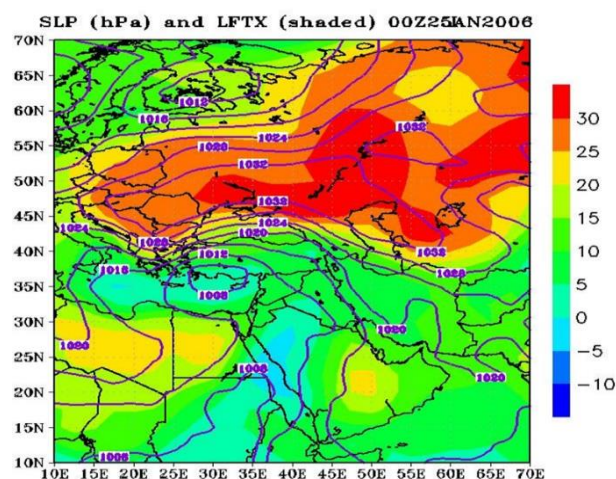
Figure (4) shows the synoptic surface map of sea level pressure for three days period in early Feb 2006 (01-03 Feb 2006). The map of 01 Feb 2006 indicates that the main feature of the pressure pattern is Omega block which influenced Iraq through its huge high pressure system located northeast of Iraq and two low pressure systems, The first is located over Italy and the second is located over Sudan. The center of the high pressure system was 1048 hPa and the centers of the two low pressure systems were 1012 and 1008 hPa respectively. On the 2nd and 3rd of February, maps show that the pressure systems were moving slowly; the high system was moving southwest and almost cover the entire country. The first low pressure was almost stationary while the second pressure system was moving northwest and eventually, the two low pressure system were merged. This situation resulted in heavy rain on 01 and 02 Feb and torrential rainfall on the third day.

Figure (5) shows the 850 hPa relative humidity and stream lines. The relative humidity was varying from 30 to 70% and systems to the moisture were fed by the Caspian Sea, Arabian Gulf, Red Sea, and the Mediterranean Sea. Figure

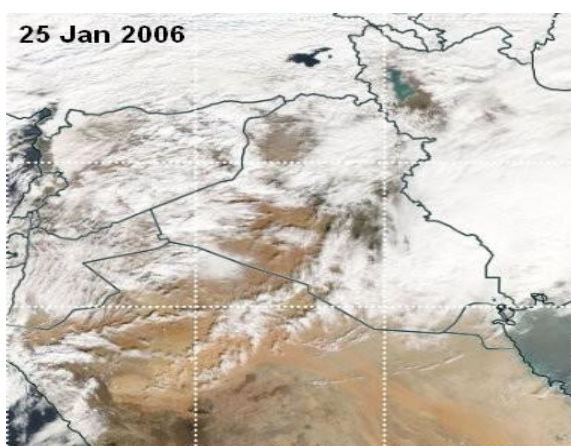


(6) illustrates the pattern of the 500 hPa relative vorticity and geopotential height.

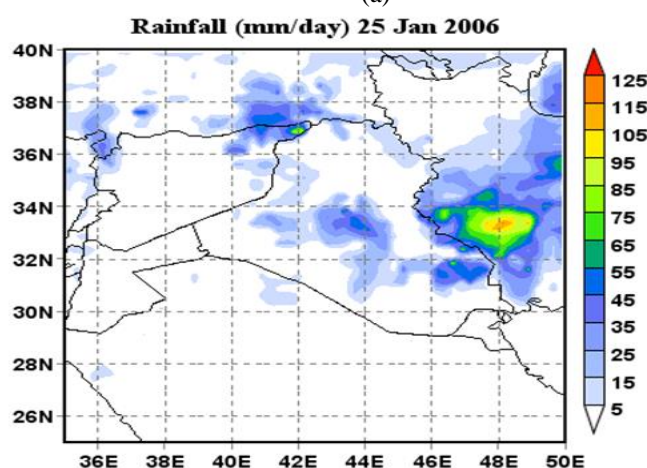
It is seen that low positive vorticity ( $0-2 \times 10^{-5} \text{ s}^{-1}$ ) was dominating the region around Iraq and higher positive vorticity to the north of the region low. Positive vorticity is produced by air spinning clockwise this is associated with high-pressure system while negative vorticity is produced by counterclockwise spinning and associated with low-pressure system. The geopotential height was varying from 550 dam to 585 dam.



(a)



(b)



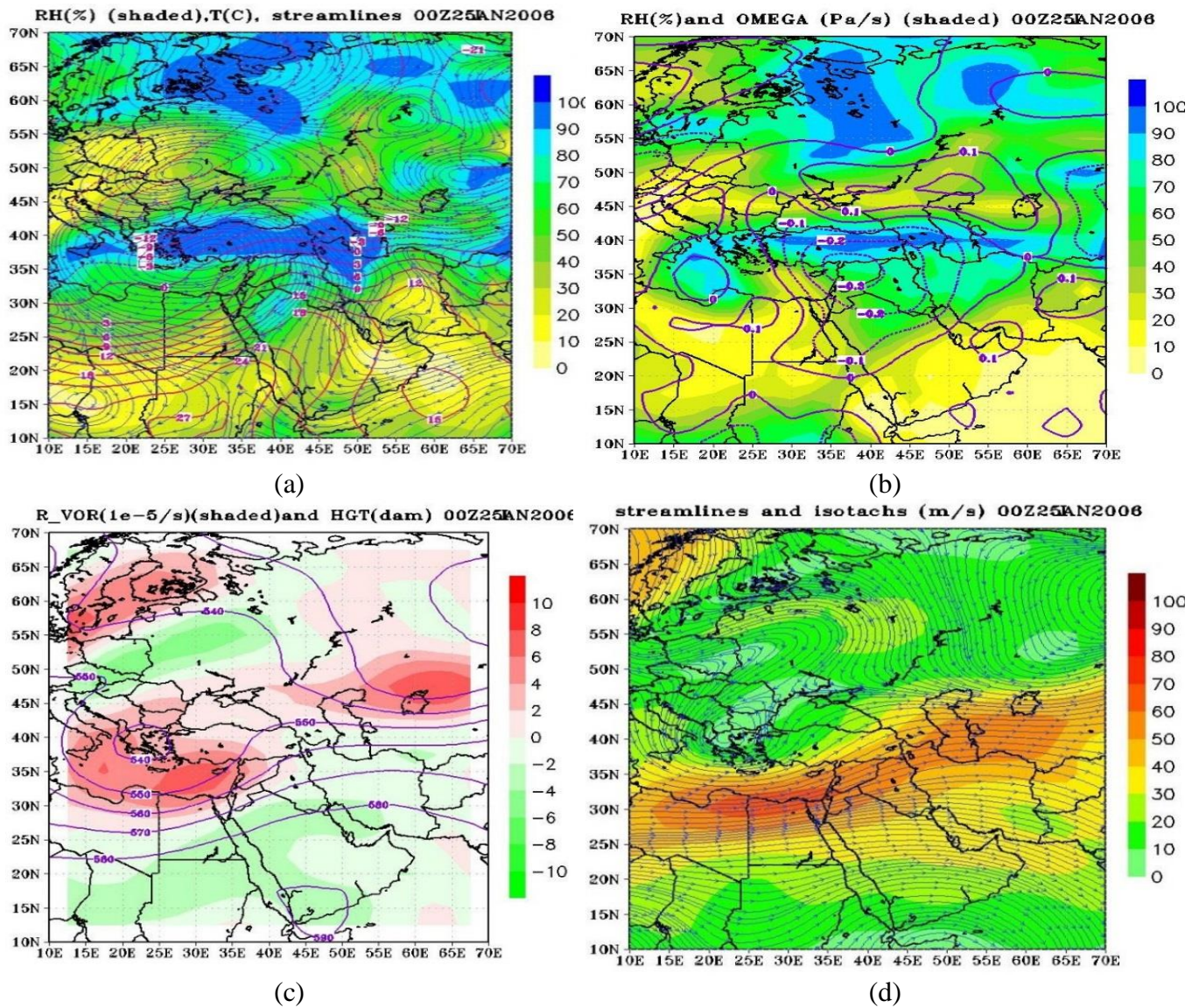
(c)

**Figure (2).** a) Surface map, b) cloud image, and c) rainfall map for 25 Jan 2006.

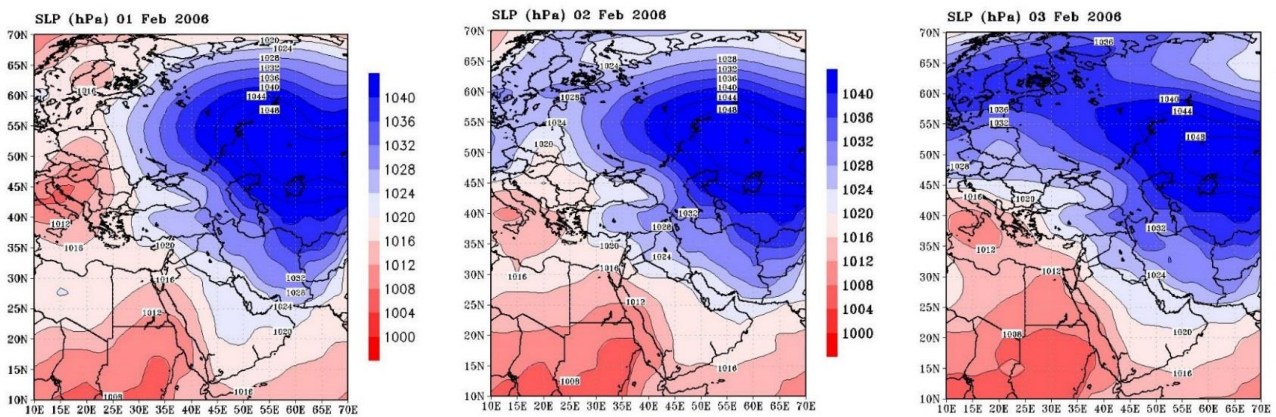
Figure (7) gives the daily rainfall over Iraq and neighboring countries during the 3 days period. The maps indicate that two rainstorms were merged to produce torrential rain of more than 150 mm/day on 03 Feb. On 02 Feb the first storm was heading from south of Turkey cross Syria towards the north of Iraq with maximum rainfall of more than 75 mm/day. On the next day, another

storm was coming from North Africa crossing the Sinai Peninsula and Jordan towards Iraq. During that day the maximum rainfall of each storm was more than 85 mm/day. On 03 of Feb, the two storms merged and produced rainfall of more than 150 mm/day over a large area covering the entire Iraq-Iran border region.



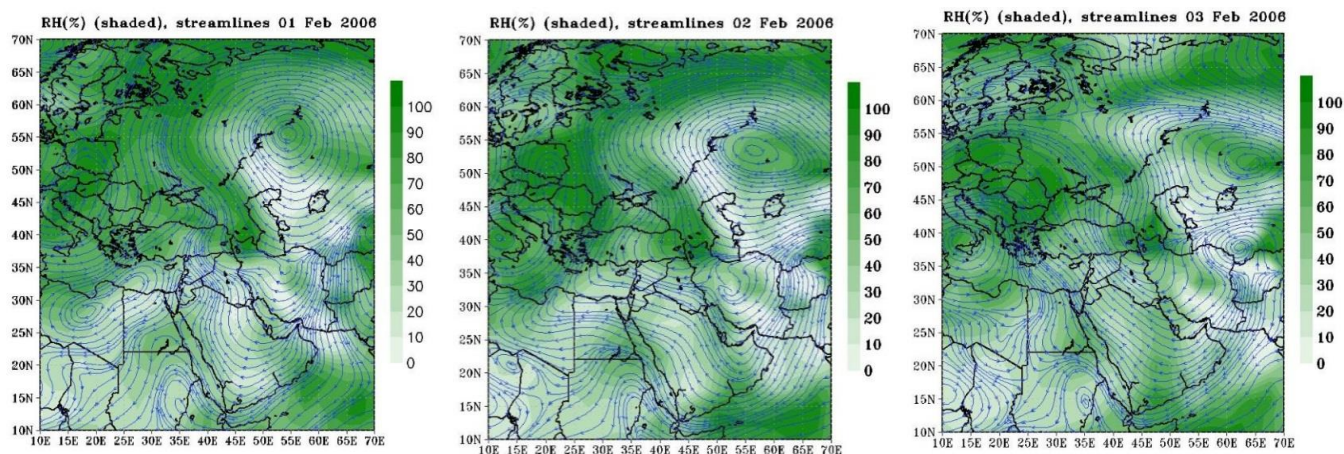


**Figure (3).** Upper air weather maps for 25 January 2006: a) 850 hPa Relative humidity (%), Temperature ( $^{\circ}C$ ), and Stream line s. b) 700 hPa Relative humidity (%) and vertical velocity (Pa/s). c) 500 hPa Relative vorticity ( $s^{-1}$ ) and Geopotential height (dam). d) 300 hPa streamlines and Isotachs (m/s).

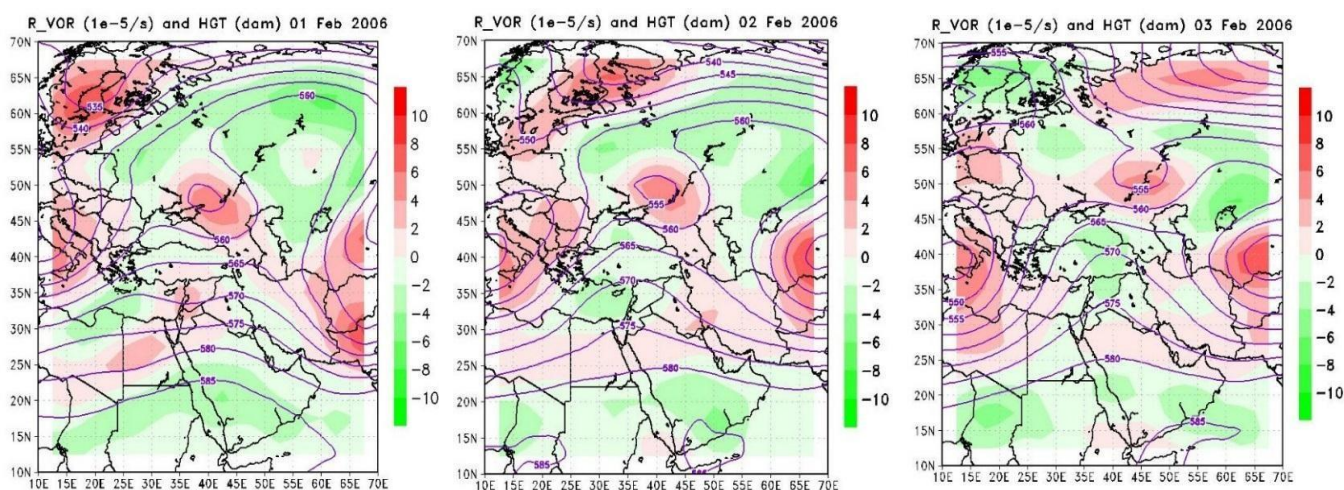


**Figure (4).** Sea level pressure maps for 01-03 Feb 2006.

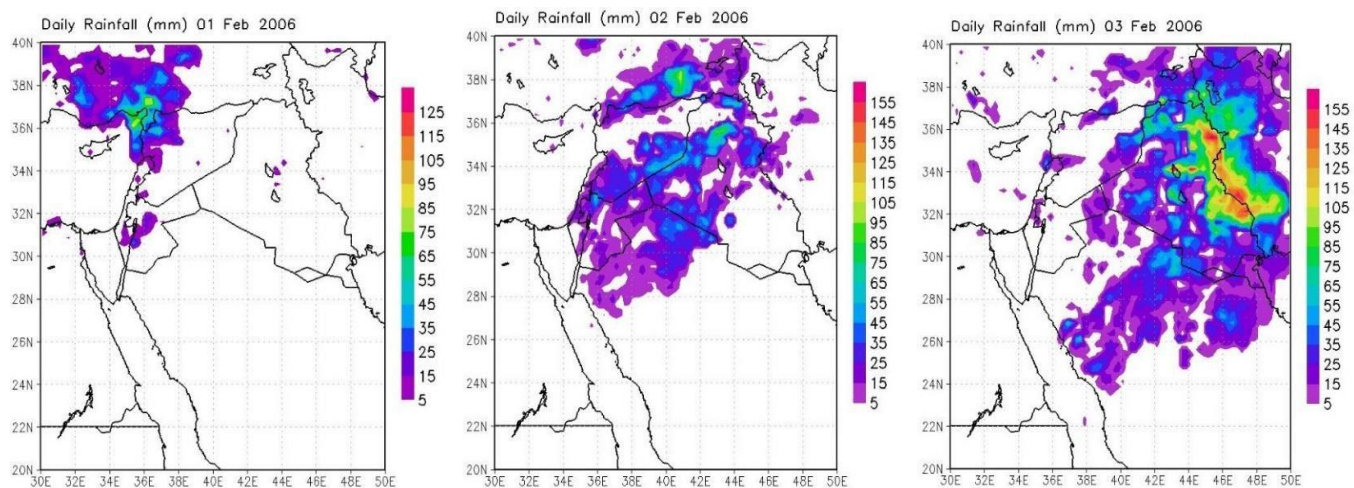




**Figure (5).** 850 hPa relative humidity (%) and streamlines maps for 01-03 Feb 2006.



**Figure (6).** 500 hPa relative vorticity ( $\times 10^{-5} \text{ s}^{-1}$ ) and geopotential height (dam) for 01-03 Feb 2006.



**Figure (7).** Daily rainfall maps (mm/day) for 01-03 Feb 2006.

## CONCLUSIONS

It can be summarized in the following conclusions:

1. Analysis of the typical year of 2016 showed that 24 blocking of various types existed. It was found that 9 out of 24 blockings were Omega block (37.5%); 4

- out of 24 blockings were Rex block (16.7%); 3 out of 24 blocking were Cut-off high blocks (12.5%); 5 out of 24 blockings were Cut-off low (20.8%); The number of Split flow block was similar to the Cut-off high blocks (12.5%).
2. It was observed that 8 events resulted in rainfall rates of more than 50 mm and 10 events produced rainfall rates between 20 and 50 mm. This means that 75% of blocking systems produced more than 20 mm rain.
  3. The results also indicate that most strong blocking was the Omega blocking that occurred on 18-23 February and resulted in 120 mm rain.
  4. Results indicated that 8 blocking events occurred in winter and in autumn, 6 blocking occurred in spring and only 2 blockings happened in summer.
  5. The moisture fed to rainstorm mainly come from by the Mediterranean Sea and the Red Sea.
  6. The amount of rainfall depends on the type of blocking causing the storm.

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