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The Daily Pattern at 500 hPa Geopotential Heights and Its Association with Heavy Rainfall over Iraq

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Abstract

Rainfall in the mid-latitudes is highly related to the synoptic pattern at the upper-levels, this study focuses on the relationship between 500 hPa geopotential height patterns and the cyclone at the surface. Synoptic studies show that there is a correlation between cyclone at the surface and deepening of the trough at the upper in the mid-latitudes. The results show that when the upper trough is situated over the eastern Mediterranean, this will enhance the advection of warm and moist air from the tropical region, which will cause baroclinic instability over Iraq, leading to heavy precipitation and torrents in some situations.

Keywords: Rainfall, Cyclone, Geopotential height, Trough, Iraq

النمط اليومي في الارتفاع الجهدي في ال(500) هكتوباسكال وارتباطه بهطول الامطار الغزيرة فوق العراق

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الخلاصة

الامطار في خطوط العروض الوسطى ترتبط ارتباطا وثيقا في الانماط الساينوبتيكية في المستويات العليا , هذه الدراسة تركز على العلاقة بين الارتفاع الجهدي في مستوى ال 500 هكتوباسكال والمنخفضات على سطح الأرض. الدراسات الساينوبتيكية أظهرت ان هنالك ارتباط بين المنخفض على السطح وتعمق الحوض في المستويات العليا في خطوط العروض الوسطى. النتائج أظهرت عندما يكون الحوض العلوي فوق شرق البحر المتوسط فأن ذلك سوف يعزز تأفق الهواء الدافئ والرطب من المناطق المدارية مما سيؤدي إلى عدم استقرار الباروكليني فوق العراق ، مما يتسبب في هطول أمطار غزيرة وسيول في بعض الأحيان.

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1. Introduction

In the first attempts to predict the weather, scientists focused on sea level pressure maps and the weather system associated with them, the extratropical cyclone was the most noticeable feature on sea level pressure maps. Later, scientists paid attention to upper-level flow and its influence on cyclones at the surface which led to understanding the weather pattern at the upper and how cyclogenesis happened and the idea of baroclinic instability[1]. Weather forecasting can be defined as the evaluation of the existing state of the atmosphere and the change that will occur[2]. The forecaster will be able to better understand weather patterns and make more accurate weather predictions if the forecast upper-level wind improves[3]. The weather systems at the surface are influenced by upper-level winds, the interaction between the low level and high level determines the strength and life cycle of the weather system[4]. A global circulation has a substantial association with a local surface variable like wind, pressure, temperature, precipitation occurrence, and temporal and spatial distribution are hugely influenced by atmospheric circulation[5]. A cyclone is a low-pressure weather system that revolves in a clockwise direction in the southern hemisphere and counter-clockwise in the northern hemisphere[6]. The flow at the upper is recognized by a trough that has cyclonic circulation or ridge that has anticyclonic circulation. The trough is accompanied by cold and unsettled weather, where the eastern side of the trough wind is stronger and enhances ascent vertical motion which may lead to precipitation if moisture is available, while the western side of the trough experiences weaker wind and subsidence[7]. The strength of the cyclone on the surface, which will lead to tempestuous weather, often happens in areas ahead of the trough axis at the upper[8].

A plethora of studies investigates the association of 500hpa geopotential height and cyclones at the surface. Sebastian et al (2020) studied the effect of trough and ridge in weather at the surface, they pointed out that not just the existence of trough and ridge was important but also their amplitude and orientation of trough played a key role in the weather system at the surface[9]. Grazzini et al (2020) pointed out that cyclogenesis at the surface was enhanced when accompanied by upper-level geopotential low which caused instability. They studied a flood that took place in Italy in November 1994, which caused a lot of casualties and losses in property[10].

Al-Nassar et al (2020) studied the extreme precipitation event in Iraq during the period between (2005-2016). They found that heavy precipitation was associated with a low geopotential height value at the upper level and advection of warm and humid air from the lower latitude[11]. Mutar et al (2021) studied the extreme precipitation that fell in Iraq in (January 28-29, 2019) which caused floods across parts of Iraq. They found out that the position of the trough at 500 hPa played a crucial role in strengthening cyclone at the surface, which enhanced instability leading to convective clouds producing heavy precipitation[12]. Haggag and El-Badry (2013) examined the heavy rainfall in November 2009 over Jeddah, they pointed out that heavy rainfall correlated with disturbance at the upper level, as the divergence at the upper-level supported convergence at the surface leading to severe convection[13].

2-Data and methods

Iraq is situated in southwest Asia between latitudes (29° 5’ and 37° 22’ N) and longitudes (38° 45’ and 48° 45’ E) [14]. It shares borders with Turkey to the north, Iran to the east, Kuwait, and Saudi Arabia to the south, while the west part of Iraq is shared with Jordan and Syria.

Iraq climate is arid to semiarid, due to the continental climate, the temperature varies considerably during the day and between the seasons where winter is cold, and summer is extremely hot where the temperature exceeds 45°C and reaches more than 50°C in the southern part of Iraq. Most of the precipitation in Iraq is the liquid rain while the snow happens in the northern region where the yearly precipitation about 213 mm, the precipitation occurs between October and April [15].

In this study, the synoptic maps were obtained from National Oceanic and Atmospheric Administration (NOAA) and Physical Sciences Laboratory (PSL) [16], which provided a wide range of archived maps for the whole world. The selected map covered the domain of longitudes 20°E to 60°E and latitudes 15°N to 50° N. Five types of maps were selected: the sea level pressure map, 500 hPa geopotential height, relative humidity at 850hpa, winds at 1000hpa, and the amount of precipitation. The value of geopotential in 500hpa was obtained from European Center for Medium-Range Forecast (ECMWF) ERA-Interim. The satellite image used in this study was obtained from NASA Worldview Snapshots [17]. The precipitation data (mm) in the study area used were provided by the Iraqi meteorological organization and seismology.

3- Results and Discussion

Two case studies of heavy precipitation were performed for different years.

A- Case study (26-29 October 2015)

The case study occurred during the period (26-29 October 2015), when heavy precipitation hit Iraq. On 26 October, Figure (1) illustrates clouds covering most parts of northern and central Iraq, while the weather in the southern parts was clear to partly cloudy.

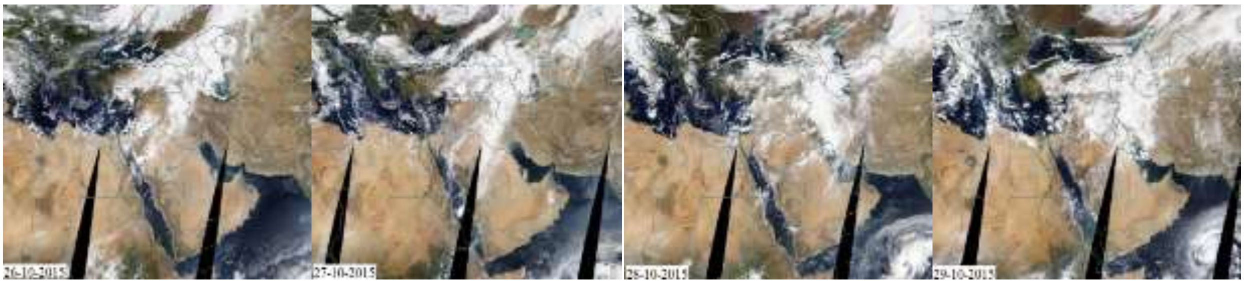


Figure 1: Satellite image shows clouds covering Iraq

The observation from the meteorological stations reported precipitation in the northern parts of Iraq. The 500mb geopotential height map shows a prominent upper-level trough stretched from Europe towards the Mediterranean Figure (2a), while the sea level pressure map Figure (2b) depicts a low-pressure system over Iraq.

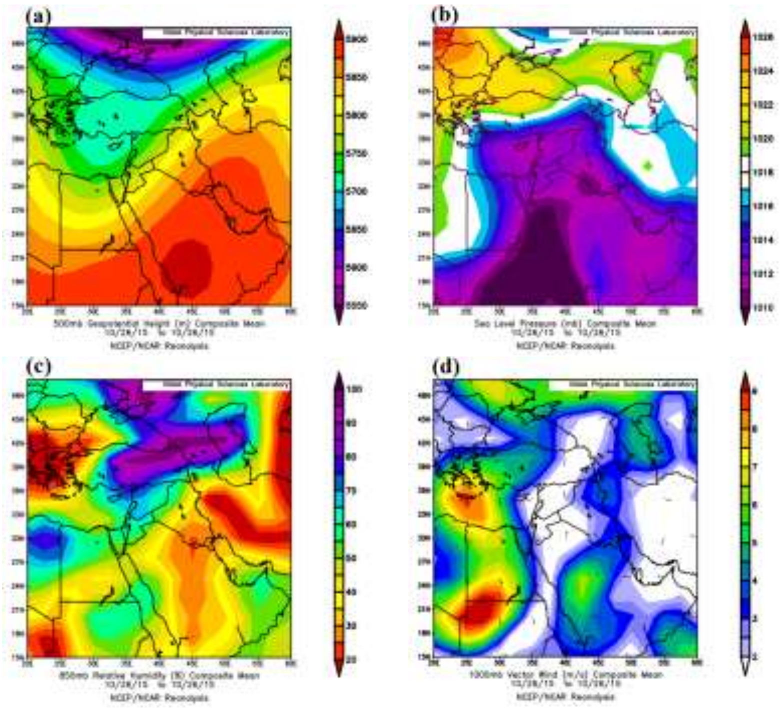


Figure 2: Composite map for 26 October 2015

The next day, the clouds covered most parts of Iraq Figure (1), with rain concentrated mostly in the northern parts of Iraq as shown in Figure (7b).

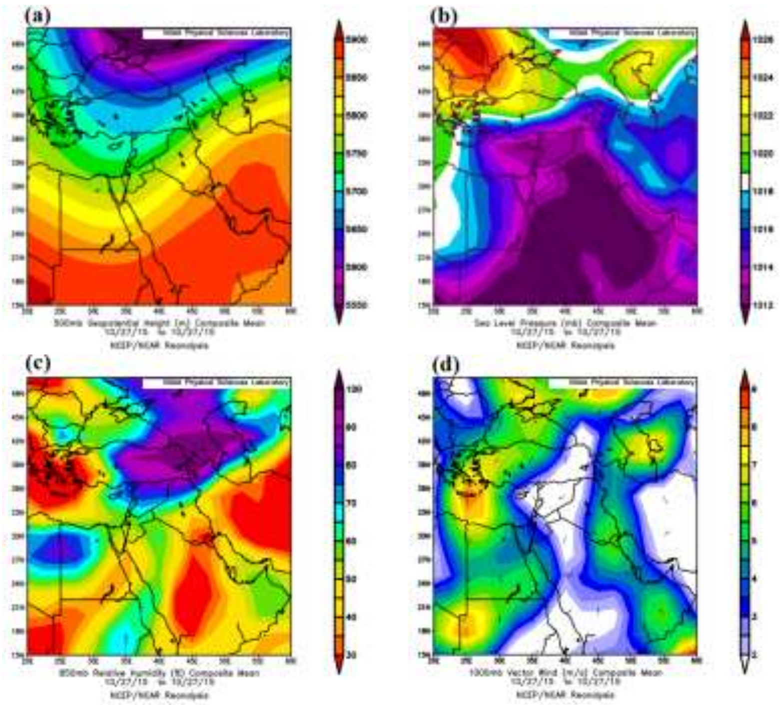
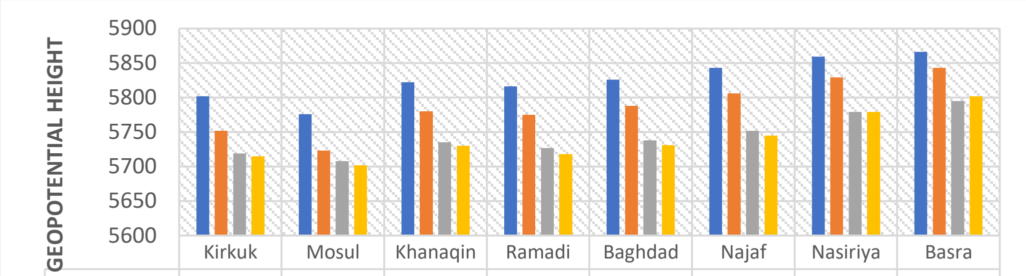


Figure 3: Composite map for 27 October 2015

On 28 October, the trough shifted eastward Figure (5a), and the value of geopotential height at 500hpa decreased in comparison to the previous days as indicated in Figure (4).



	Kirkuk	Mosul	Khanaqin	Ramadi	Baghdad	Najaf	Nasiriya	Basra
26/10/2015	5802	5776	5822	5816	5826	5843	5859	5866
27/10/2015	5752	5723	5780	5775	5788	5806	5829	5843
28/10/2015	5719	5708	5735	5727	5738	5752	5779	5795
29/10/2015	5715	5702	5730	5718	5731	5745	5779	5802

Figure 4: Shows the values of 500hpa Geopotential Height for 8 stations in Iraq during the periods (26-29 October 2015)

The upper divergence at the eastern parts of the trough enhanced convergence at the surface leading to ascending motion which would cause the strengthening of low pressure at the surface. The pressure at Baghdad station at 1200z was (1009hpa), meanwhile the south-easterly wind advected moisture and heat towards the region Figure (5d). The source of moisture, in this case, was the red sea and Arabian Gulf, the relative humidity exceeded 80% in the northern parts of Iraq, while at the rest parts of Iraq fluctuated between 50% to75% Figure (5c).

The presence of cold upper trough, moist and warm air at the surface led to baroclinic instability. The atmosphere became highly unstable, triggering strong convection causing heavy rainfall in some parts of Iraq as shown in Figure (7c). The reports showed that the amount of rainfall in Baghdad was 54.1 mm, while the khanaqin station recorded 38.2 mm and Najaf station recorded 32.3mm.

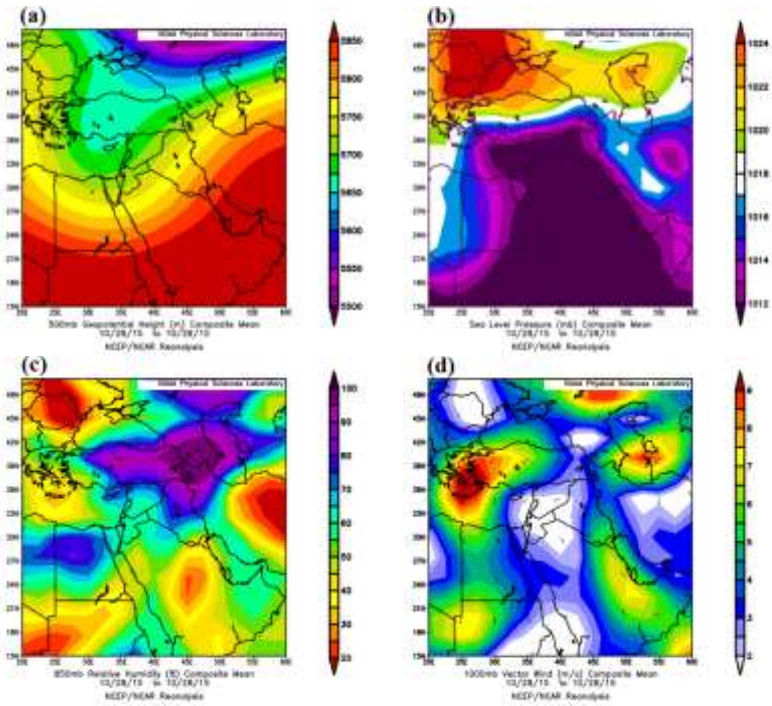


Figure 5: Composite map for 28 October 2015

On 29 October, the instability case affected mostly the eastern part of Iraq which caused heavy precipitation in this region Figure (7d). The relative humidity at 850 hPa reached in the northern and eastern parts of Iraq more than (80%). The amount of rain that fell in khanaqin, which is situated in the eastern part of Iraq, was 47.4 mm.

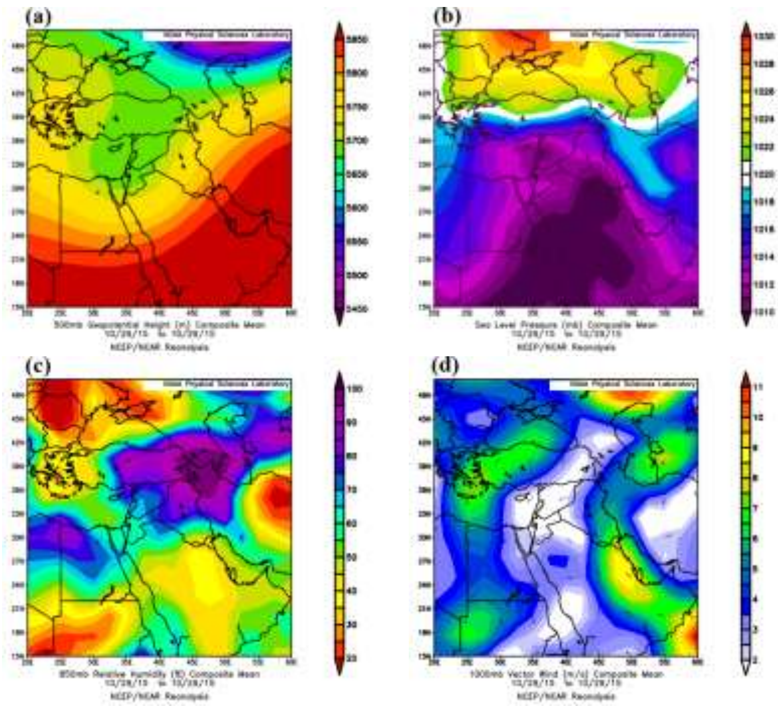


Figure 6: Composite map for 29 October 2015

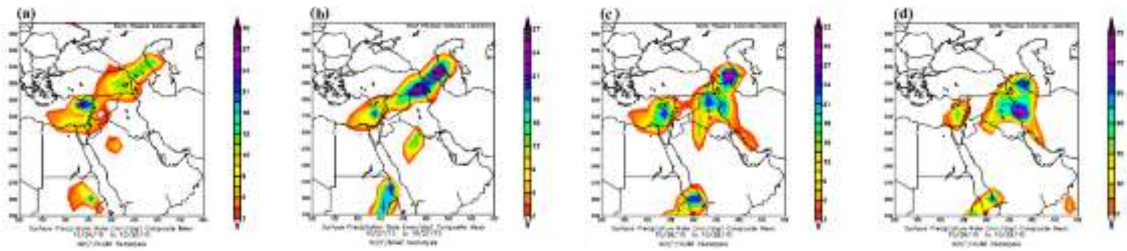


Figure 7: Illustrates the amount of rain that fell during the period (26-29 October 2015**)**

B- Case study (30 March - 1 April 2019)

From 30 March to 1 April 2019 precipitation events concentrated mostly in the eastern parts of Iraq.

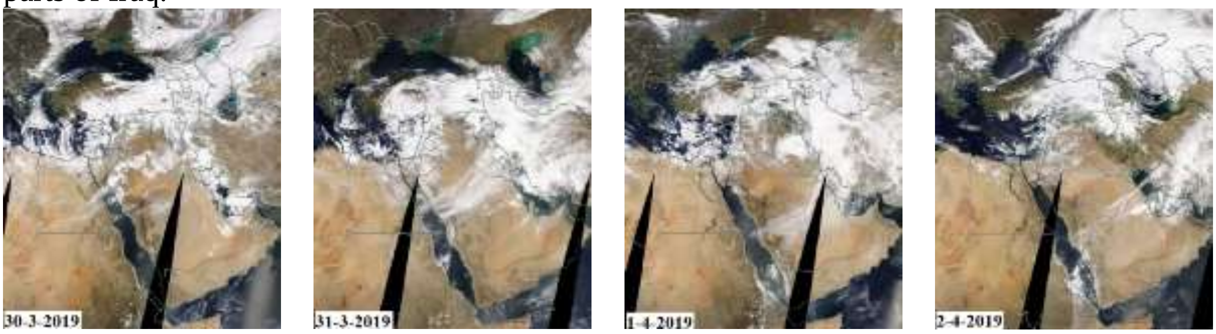


Figure 8: Satellite image shows clouds covering Iraq

On 30 March, the 500mb geopotential map shows a cut off low over the Mediterranean Figure (9a). The sea level pressure map shows an extratropical cyclone over the Mediterranean which what we call the Mediterranean low-pressure. The Iraqi meteorological stations reported moderate rainfall amount in the northern parts of Iraq while the weather in the central and southern parts of Iraq was cloudy with scanty rain in some stations.

On 31 March, The cut-off low moved eastward and shifted southward to about 25N Figure (10a), this caused to strengthen the low pressure at the surface, and the south easterly winds advected moisture towards the region Figure (10d). While the cold air at the upper caused baroclinic instability, the relative humidity in the northern and eastern parts of Iraq exceeded 90% Figure (10c). Most Iraqi stations recorded precipitation, and the amount of rainfall that fell in Kirkuk was about 28mm.

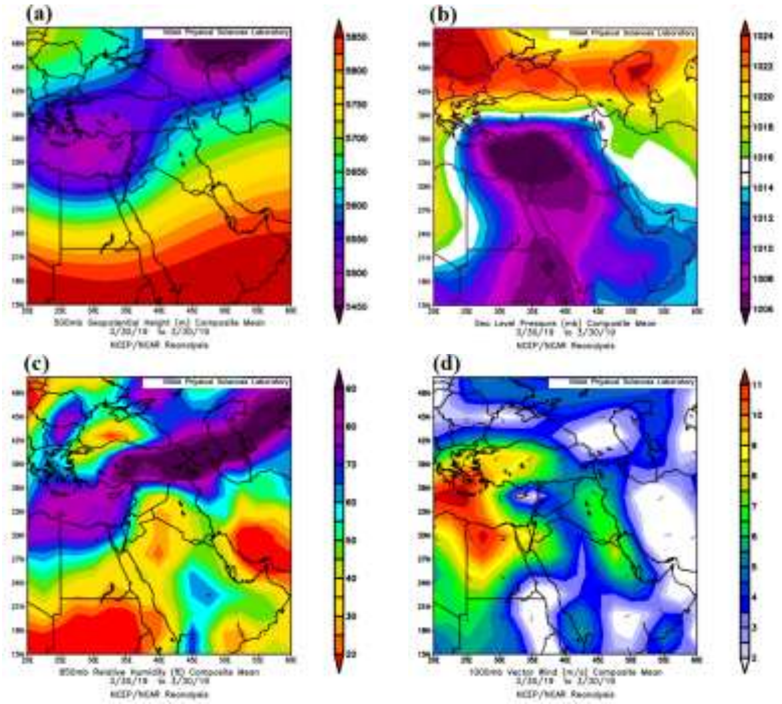


Figure 9: Composite map for 30 March 2019

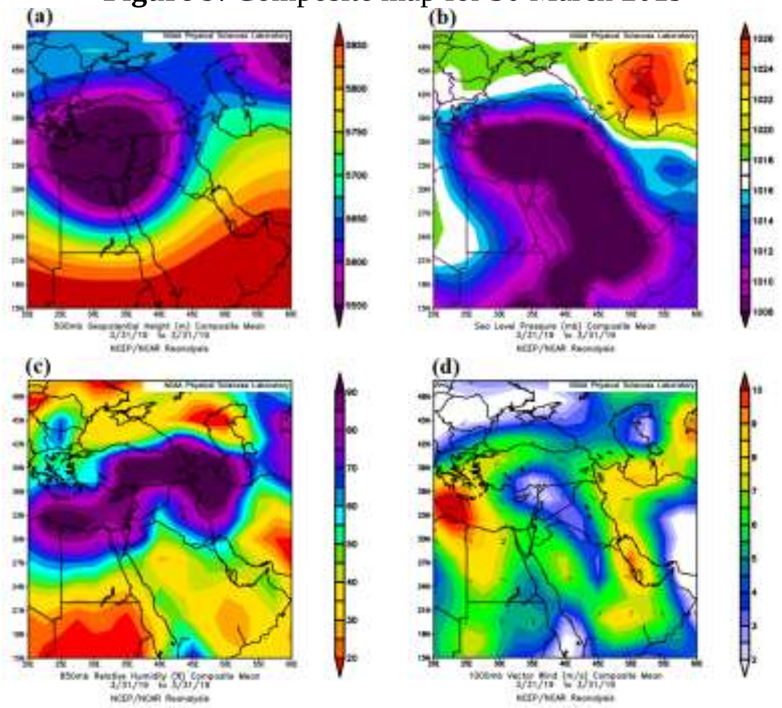
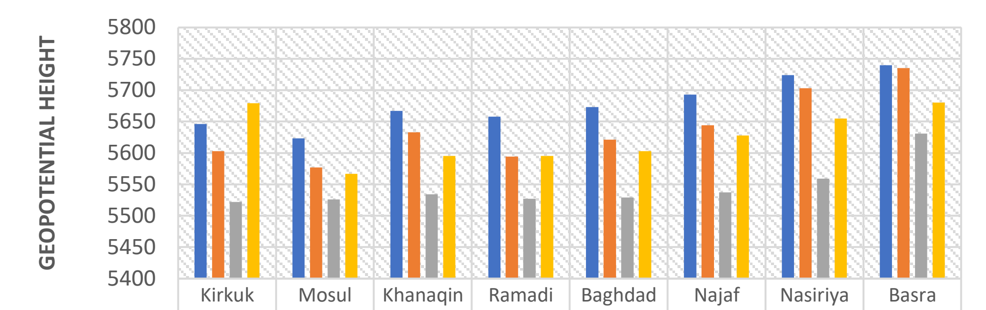


Figure 10: Composite map for 31 March 2019

On 1 April 2019, the cut-off low deepened and situated over Iraq Figure (12a). The geopotential height at 500hpa value decreased sharply over Iraq; which means that the thickness between 500hpa and the underlying surface had decreased as an indicator of cold advection. The value of geopotential height over Baghdad was (5529gpm), while in the previous day the value of geopotential height was (5621gpm) Figure (11). This leads to high instability, particularly in the eastern parts of Iraq which causes thunderstorms and heavy rainfall and causes torrents across the Iraqi-Iranian border Figure (13).



	Kirkuk	Mosul	Khanaqin	Ramadi	Baghdad	Najaf	Nasiriya	Basra
30/3/2019	5646	5623	5667	5658	5673	5693	5724	5740
31/3/2019	5603	5577	5633	5594	5621	5644	5703	5735
01/04/2019	5522	5526	5534	5527	5529	5537	5559	5631
02/04/2019	5679	5567	5595	5595	5603	5628	5655	5680

Figure 11: Shows the values of 500hpa Geopotential Height for 8 stations in Iraq during the period (30 March-2April 2019)

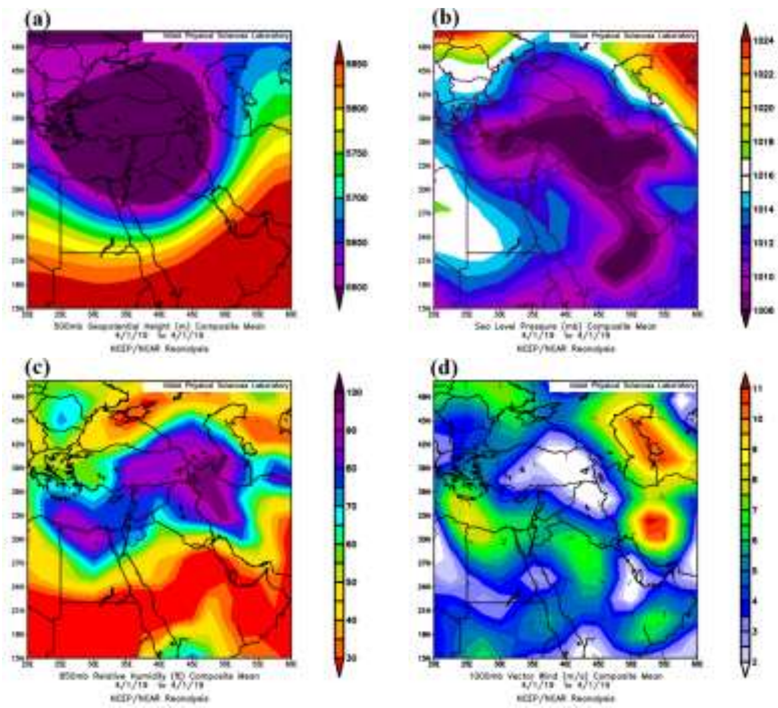


Figure 12: Composite map for 1 April 2019

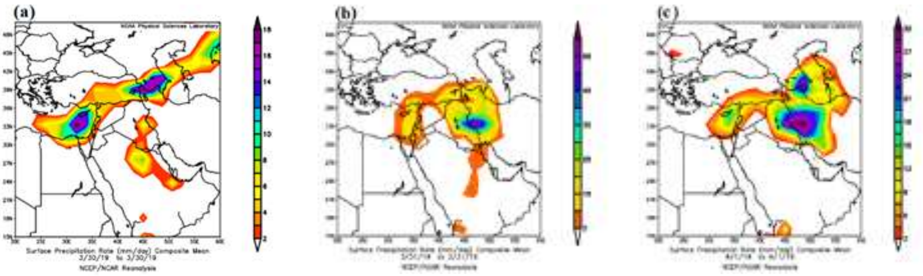


Figure 13: Illustrates the amount of rain that fell during the period (30 March-1 April 2019**)**

4- CONCLUSION

The aim of this paper is to study the correlation between variation at 500hpa geopotential height and the Cyclone at the surface, which may produce extreme weather events. The cyclone in the mid-latitude is strongly related to the synoptic pattern at the upper level. There is a connection between the trough at the upper and the behaviour of cyclones at the surface. We analysed two cases from different years, the result showed that when the upper trough is situated at the eastern Mediterranean and propagates southward will promote the advection of warm and moist air from the equatorial region which will cause baroclinic instability over Iraq, leading to heavy precipitation. The strength of the cyclone at the surface depends on the trough location and its orientation. The geopotential height pattern at the 500 hPa map gives a clear indication of the state of the atmosphere in the lower levels.

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