Research Article

A Comparative Study Between Short Life- Cut off Low and Long Life-Cut off Low Accompanied by Heavy Precipitation Storms Over Iraq: Case Study

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ArticleInfo

ABSTRACT

Received 21/10/2019

Accepted 06/01/2020

Published 15/04/2020 A comparative study between Short Life Cut Off Low (SL-COL) extended for one day, and Long Life Cut Off Low (LL-COL) extended for ten days associated with successive rain storms over Iraq on 21 to 30 April, 2018. The study tracking the evolution stages of both COLs in different pressure surfaces at troposphere layer, and found that there are many dynamical processes effect on prolong the life of COL. These processes exchanged their roles between different pressure levels. In both cases the high potential vorticity (PV) anomaly at 315° K isentropic surface is responsible on the emergence COLs, and the convection processes at lower troposphere and latent heat at upper troposphere are responsible on COLs dissipation. The main reasons of long-life COL can be summaries as a high-pressure system below COL at the surface which preventing the convection process, the formation of Omega block that promoting the COL system and preventing its dissipation rapidly in spite of the intense convection processes due to tropical moist system at the surface.

KEYWORDS: Long Life-Cut off low; Short Life-Cut off low; Omega block; Rex block.

الخلاصة

اجريت دراسة مقارنة بين منخفض قطع قصير العمر امتد ليوم واحد ومنخفض قطع طويل العمر امتد لمدة عشرة ايام رافقت عاصفتين مطريتين متتاليتين فوق العراق خلال الفترة من ٢١-٣٠ نيسان (ابرل) ٢٠١٨. خلال متابعة مراحل تطور كلا النمطين لمستويات ضغطية مختلفة ضمن طبقة التروبوسفير وجدت الدراسة بان هناك العديد من العمليات الداينميكية التي تؤثر على فترة بقاء منخفض القطع، وان هذه العمليات يتغير تاثير كل منها مع تغير المستويات الضغطية. في كلا حالتي منخفض القطع قصير العمر وطويل العمر وجد ان هنالك شذوذ (ارتفاع) في قيمة الجهد اللولبي Potential Vorticity منخفض القطع قصير العمر وطويل العمر وجد ان هنالك شذوذ (ارتفاع) في قيمة الجهد اللولبي Potential Vorticity (PV عند سطح تساوي درجة الحرارة الجهدية N ما50 مع نشوء كلا النمطين، فيما كانت هناك عمليات حمل حراري عند السطح اسفل طبقة التروبوسفير وحرارة كلمنه في الاعلى مسوؤلة عن تلاشي نمطي منخفض القطع. استنتجت الدراسة ان السطح اسفل طبقة التروبوسفير وحرارة كامنه في الاعلى مسوؤلة عن تلاشي نمطي منخفض القطع. استنتجت الدراسة ان على السلح اسفل طبقة التروبوسفير وحرارة كلمنه في الاعلى مسوؤلة عن تلاشي نمطي منخفض القطع. استنتجت الدراسة ان معلى السلح اسفل طبقة التروبوسفير وحرارة كامنه في الاعلى مسوؤلة عن تلاشي ملعي منطع مراري عند من عالم السلح البقل عمر منخفض القطع المرافق لاحدى العاصفتين المطريتين يمكن تلخيصه بوجود مركز مرتفع جوي على السلح السفل نمط منخفض القطع ينع حدوث عمليات حمل حراري تسرع من عملية تلاشي منخفض القطع ور مرتفع جوي معلى السلح المال نمط منخفض القطع يدو حو عمليات حمل حراري تسرع من عملية تلاشي منجور مركز مرتفع جوي وحيود عمليا حمل مندفض القطع يماع وهو حاجز ضغطي يعزز منخفض القطع ويمنعه من التلاشي على الرغم من وجود عمليات حمل حراري على السطح بسبب وجود مكون مناطع ومنات على مالولي منه عليه على الرغم من

INTRODUCTION

Cut Off Low pressure systems (COLs) are closed lows formed in the upper troposphere [1], separated from the westerly planetary flow, in which it initiated when the meridional jet stream deforms upper trough and deepening it, till it separated from the main flow due to the cold air advection in the west and equatorward side [2]. The intrusion of lower stratospheric air and the upper tropospheric layer is ruled by mesoscale processes in the extratropical region and leading to formation COLs, tropopause folding, and closed anticyclone (CA) in which COL system and tropopause folding control on irreversible exchange processes in the mid latitude [3]. This intrusion can be diagnosed by the high value of potential vorticity PV at the upper troposphere linked with reinforced ridge, and expansion of trough deepening in the middle troposphere [4]. Upper closed low and closed high are contributing in the thermal transfer process between polar air and tropical air [5]. The temperature gradient associated with this process creates a baroclinic wave in the eastern edge of COL responsible of its





development. COL is a type of blocking called blocking when the systems do not progress along the latitude belt in the westerly flow. There are other types of blocking, the most common one is Rex block; its high over low. The other type is Omega block; it consists of a ridge in between tow lows [6]. There are four stages of COL evolution: in the first stage, the deepening in upper trough occurs due to cold air advection; the second stage begins when a closed circle forms in the center of upper deepen trough; while in the third stage, the upper trough loses the contact with westerly flow and form COL; the COL disappears in the last stage when it merges with main westerly flow. Continuous precipitation is the common weather associated with COL system below its and westerly edges [7]. easterly Manv researchers studied COL and investigated the reasons behind its occurring. However, some of them interested in upper troposphere and stratosphere-troposphere interaction, the others concerned in lower and middle troposphere processes such as cyclogenesis, cloud cover, precipitation, and deep convection. (Kentarchos 1998) studied COL system and Davies. statistically for five years, they focused on its duration, position, size, and movement, and they found that the long life COL system (lasted more than 3 days) moves for a distance greater than 600 km. The stage of decay started when it moves northwards or eastwardsnortheastwards [8]. A dynamical study by (Baray et al., 2003) investigated the impact of tropical COL pressure system on the rate of ozone in the upper troposphere. The study suggested that the impact of the intrusion of stratosphere in the upper troposphere has a significant effect on the life period of tropical COL more than subtropical and polar COL [9]. (Nieto et al., 2005) examined COL pressure systems for long period of time in order to understand its climatological features in the northern hemisphere. They found first the most common area of COL occurrence is in the south of Europe, eastern Atlantic coast, eastern north Pacific, and northern China-Siberian region; secondly the COL is formed in Summer months more than winter months, and thirdly the COL has a short life [10]. Climatological and statistical study was done by (Nieto et al., 2007) on COL in the European sector. They

systems, the pressure patterns stated that there is a seasonally relationship between COL occurrence and large scale phenomenon such as NAO in Autumn and blocking in Winter, but in Summer which represents the season of most COL occurrence, there was no clear influences [2]. (Porcù et al., 2007) classified COL episodes over the Mediterranean region depending on vertical structure of surface cyclone and the patterns of precipitation associated with spring and summer months. They found that short life COLs are more frequent in Summer months and September, while long life COLs are more active in June [11]. In the present paper, a comparative study is done between two successive heavy precipitation storms over Iraq from 20 to 30th of April, one of them accompanied with Short Life Cut Off Low (SL-COL), while the second is accompanied with Long Life Cut Off Low (LL-COL), and follow up associated dynamical processes at different pressure surfaces in troposphere layer. The reason behind that is to explore the main dynamical processes that effect on the life duration of COL.

MATERIALS & METHODOLOGIES

In order to compare between LL-COL and SL-COL, this study will track their development through different pressure surfaces of tropospheric layer, including the upper, the mid, and the low pressure surfaces at (150, 500, 700) hPa respectively in addition to the sea level pressure.

The ERA-Interim reanalysis data model by European Center for Medium-Range Weather Forecasting (ECMWF) were used for the domain extended from (10°W-60°E) longitude, and (20°-70°) N latitude with a resolution of 0.25x0.25. ERA-Interim is the latest global atmospheric reanalysis produced by the ECMWF*. ERA-Interim covers the period from 1 January 1989 onwards, and continues to be extended forward in near-real time. Information about the current status of ERA-Interim production, availability of data online, and near-real-time updates of various climate indicators derived from ERA-Interim data, can be found at:

http://www.ecmwf.int/research/era.

Gridded data products include a large variety of 3-hourly surface parameters, describing weather as well as ocean-wave and land-surface conditions, and 6-hourly upper-air parameters covering the troposphere and stratosphere. Vertical integrals of atmospheric fluxes, monthly averages for many of the parameters, and other derived fields have also been produced [12]. In this study, the data of meteorological parameters were used for each 12 hr for two heavy precipitation storms prolonged from 22 to 30th of April in 2018. The data included a zonal wind U, and potential vorticity PV at 315° K isentropic surface, air temperature at 150 hPa, geopotential height and vorticity at 500 hPa, vertical velocity at 700 hPa, mean sea level pressure and convective precipitation at the surface.

RESULTS AND DISCUSSION

In order to compare between LL-COL and SL-COL, we will investigate their development through different pressure surfaces of tropospheric layer: upper (150 hPa), mid (500 hPa), lower (700 hPa), and sea level pressure.

Case One-Long Life-COL (LL-COL)

This item includes the synoptic and dynamical analysis of (LL-COL), and it will be labeled as (L1) in charts and analysis. It started to form at 12 UTC on April 21, 2018, and continues for 10 days till it dissipated at 18 UTC on April 30, 2018. It is classified as eight stages representing the beginning, evolution and finally the ending of this case.

1. The initial state of LL-COL(L1): On April 21 at 00 UTC as shown in figure 1(a), there was a closed circle of high PV with a value of more than 2.5 PVU at 315° K isentropic surface (the 315° K level is located near 400 hPa at low latitude in subtropical area and reaches to the about 250 hPa at high latitude); over west of Mediterranean Sea associated with а stratospheric warm air mass at 150 hPa and jet stream. Beneath the tongue of high PV region at 315° K in the eastern Mediterranean, there is a base of 500 hPa trough of cold air, and the jet stream enforcing ascent motion in the eastern side of the trough. A meridional deformation is formed leading to produce short wave in the base of the trough. The positive tilt of the trough will enhance positive and negative

vorticity in the cyclonic and anticyclonic side of trough's upstream respectively. At the same time there is a closed area of tropospheric cold air at 315° K isentropic surface over southwestern of Europe, with Closed Anticyclone (CA) beneath it. The CA is bordering to west flank of the trough and will increase the descent of air in this region as shown in Figure 1(b). At 500 hPa, there is a positive vorticity in the base of cold air trough Figure 1(c), and weak vertical velocity beneath it at 700 hPa Figure 1(d) due to the existence of highpressure center at sea level pressure located to the southwest of Europe and the west Mediterranean Sea Figure 1(e).

- 2. The onset of LL-COL(A): On April 21 at 12 UTC, Figure 2(a), and 2(b), the region of the descend at the eastern side of CA and upstream of adjacent trough at 500 hPa is bending from south-west to west due to gradient wind, accompanied with easterly jet that separates the CA from the base of trough (the region of cold air) and form COL, leading to produce a pattern of Rex block, in which the easterly jet is the abnormal feature of Rex block. The new COL (A) is located beneath PV anomaly at 315° K isentropic surface and the warm air mass at 150 hPa. Figure 2(c), 2(d), and 2(e), also, there is a (positive/negative) relative vorticity at the center of (COL/CA) at 500 hPa, while the vertical velocity (ascent/ descent) at 700 hPa respectively is weak and this is due to the strong high pressure at the surface, preventing the evolution of COL (A).
- 3. The dissipation of CA and intensification of LL-COL(A): On April 22 at 00 UTC, Figure 3(a), and 3(b), the region of tropospheric cold air is reduced at 150 hPa, which in turn weakens the CA at 500 hPa. On the other hand, the COL intensified at the same level due to the enhancement of warm air at 150 hPa at 00 UTC, with a slowly movement of positive/negative relative vorticity around the circle of COL(A)/CA respectively as shown in Figure in addition to weak 3(c), а negative(ascend) and positive(descend) vertical velocity at 700 hPa Figure 3(d) due to strong high pressure at the surface Figure 3(e).







Figure 1. Synoptic and dynamical charts for case (1) on April 21 at 00 UTC stage one: (a) the black solid contour line represents geopotential height at 500 hPa of interval 30 gpm, the black shaded represents the jet stream in m/s at 315° K potential temperature surface, and the color solid contour line represents potential vorticity in m k/kg² s² of interval 1 PVU(1E⁻⁶ m k/kg²s²) on 315°K potential temperature surface, (b) color shaded represents temperature at 150 hPa in Celsius, the color solid contour line as in (a), (c) the black solid contour line as in (a), white contour line represents the (1000-500) hPa thickness line of interval 60 gpm, and color shaded represents relative vorticity in s⁻¹ at 500 hPa, (d) the black solid contour as in (a), color contour line represents vertical velocity at 700 hPa in(pa s⁻¹) of interval 0.4 pa s⁻¹, red contour represents ascent air, blue contour represents descent air, (e) the black solid contour line as in (a), white contour line as in (a), white contour line represents mean sea level pressure of interval 2 hPa, and color shaded represent the convective precipitation in mm.

b

d

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Figure 2. Same as in Figure 1 but at 12 UTC 21 April.

Figure 4(a), and 4(b), according to the current state, the CA has disappeared at 1200UTC of the same day, and COL is intensified at 500hPa associated with upper high PV anomaly and jet stream at 315° K isentropic surface and warm stratospheric air at 150 hPa. The positive relative vorticity increased around the center of COL(A), due to negative vertical velocity (ascend) beneath the center of COL(A) at 700hPa Figure 4(c) and 4(d), and the center of high pressure weakens at the surface, this situation leads to a small rate of convection precipitation beneath COL(A) Figure 4(e).

4. The steady state of LL-COL(A): During the period of (23-25) of April, there was no evolution in the state of COL(A) due to the domination of high-pressure system at the surface leads to preventing any modification in COL (A) at 500hPa in spite of the presence of high PV at 315° K isentropic surface and this state is to be discussed in the discussion





section. It is worth to mention that there is another COL was created over western Iraq and

labeled as SL-COL (B).





5. The intensification of LL-COL(A): On April 25 at 00 UTC, the COL moved southeasterly reaching the land of North Africa, and intensified by warm and moist tropical Red Sea Trough (RST) pressure system at the surface in spite of the weaken PV anomaly at 315° K at isentropic surface and the reduction in warm air mass at 150 hPa as (not shown). Positive relative vorticity has intensified too around

COL (A) with increase in negative vertical velocity at 700 hPa (not shown). This situation leads to increment in convection at the surface and latent heat at the upper level at 12UTC as shown in Figure 5(a), and 5(b), with increasing negative vertical velocity at 700hPa and positive relative vorticity around COL(A) as shown in Figure 5(c), and 5(d). Thus, high rate of convection precipitation at surface beneath

eastern flank of COL (A) has occurred Figure 5(e). This state has continued for the next day 26 of April 2018 due to the presence of high PV at 315° K isentropic surface, and the continues deepen in RST pressure system at the

surface. It is noticed that another COL(C) located over west northern Africa which will participate in the formation of Omega block system in the next stage.



Figure 4. Same as in Figure 1 but at 12 UTC 22 April.

6. **The formation of Omega block:** On April 27 at 12 UTC, an Omega block formed at 500 hPa due to rise warm air from deepen surface cyclone over northwest Africa leading to increase negative vertical velocity (ascend) at 700hPa and positive relative vorticity at 500hPa Figure 6(c), and 6(d), that enhanced upstream (downstream) side of the upper ridge (left trough), while the high pressure system at the surface below the center of the ridge of Omega block will enhanced descend in the









COL(C) at the left side of Omega block formed due to closed region of high PV anomaly at 315K isentropic surface associated with warm air at 150hPa, while the COL(A)lies at the right side of Omega block. Omega block and RST low system at the surface prolong the life of COL (A), in spite of disappearance of high PV anomaly and the reduced region of warm air at 150hPa over it and high convection due to surface RST cyclone Figure 6(a), and 6(b). Earlier at 00 UTC of the same day, COL (A) reached western board of Iraq associated with high rate of convection precipitation over the western region of Iraq (not shown). Later, the rate of convection precipitation extended over the whole country at 1200UTC due to advanced COL (A) system toward Iraq Figure 6(e).

b

d





7. The weaken of Omega block: On April 28 at 00 UTC, RST pressure system was deepening and reached 1000 hPa over Iraq, which increased the convection precipitation rate due to intensification of convection process (ascend) due to positive relative vorticity at the center of the deepen COL(A) at 500hPa Figure 7(a), 7(b), 7(c), and 7(d). At the same time on the right side of Omega block, there is a high

pressure system at the surface which enhanced the descend of air at this region accompanied with weaken of the ascend air in the left side of Omega Block due to the movement of surface low pressure system beneath it, leading to an increment of zonal wind compared to meridional wind. The current situation has led to dissipate the ridge of Omega block and form a closed anticyclone (CA).





Figure 7. Same as in Figure 1 but at 00 UTC 28 April.

8. The dissipation state of LL-COL(A): on April 30 at 1200 UTC, both COLs that formed omega block were getting weak due to latent heat process, and the both low pressure systems at surface are filled and weaken, which reduces the convection processes, but the CA with Omega block still strong associated with strong high pressure system at the surface Figure 8(a), 8(b), 8(c), and 8(d) that leads to break Omega block and solved COLs system at 18 UTC (not shown).

Case Two-Short Life-COL (SL-COL)

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This item includes the synoptic and dynamical analysis of (SL-COL), and it will be labeled as (B) in charts and analysis. It started to form at 12 UTC on April 21, 2018; and continues for 24 hours till it dissipated at 12 UTC on April 23, 2018.

Below are the stages of the formation, developments and dissipation of this case:

1. The initial state: at 12 UTC on April 21 stratospheric warm air at 150 hPa extending with a tongue of high PV anomaly from northwest Asia toward the southwest over

south Europe and eastern Mediterranean Sea Figure 2(a). A jet streak associated with PV anomaly in its east flank, where upper front is located due to the different characteristic for adjacent air masses of stratosphere and troposphere. Beneath it, there is a trough of cold air at 500 hPa with positive tilt. The jet stream causes cold polar air rush towards the equator which deepening the trough at 500 hPa, and producing stable baroclinic wave at the west flank of trough, intensified cyclone (anticyclone) vorticity at the right (left) flank of the trough Figure 2(b). The positive tilt of the trough will enhance the cyclone at the surface as in Figure 2 (c). In Figure 2(d) we can see a positive (negative) vertical velocity at 700 hPa beneath the right (left) flank of 500 hPa trough explain which the surface cyclone intensification. Figure 2(e) show surface cyclone (Indian monsoon) below east flank of upper trough (region of ascending air), which activate the cyclone associated with rate of convective precipitation.





Figure 8. Same as in Figure 1 but at 12 UTC 30 April.







Figure 9. Same as in Figure 1 but at 12 UTC 23 April.

2. The onset of SL-COL (B): at 12 UTC On April 22 Figure 4(a) show a thin tongue of PV anomaly with mass of stratospheric warm air over north-west of Iraq, the jet stream in Figure 4(b) deflect poleward that will change the tilt declination of the cold trough eastward at 500 hPa and then will promote baroclinic instability in the trough downstream. the meridional deflection of jet stream will increase (decrease) cyclonic (anticyclonic) vorticity downstream (upstream) at 500 hPa trough that will strength the low system at surface, leading to form a COL (B) by cutting off the system from main flow as shown in Figure 4(c). negative vertical velocity increased under downstream of upper trough which reinforced convection process at the surface and latent heat at the upper level that presented in Figure 4(d). the cyclone deepens at the surface and reaches to 998 hPa on 22 April at 12 UTC, while it was 1004 hPa before 24 hours, and there is an increment in the convective precipitation rate beneath the eastern side and around the center of COL (B) Figure 4(e).

3. The dissipation stat of SL-COL(B): at 12 UTC On April 23, a dissipation of the warm air mass with a retreat and weaken PV anomaly tongue is taking place as shown in Figure 9(a), with a transmission of the jet stream eastward over Iran Figure 9(b). COL (B) has disappeared and merge with the main trough, in which the main trough is filled and move eastward Figure 9(c), since the upper trough move eastward of Iraq, there is no negative vertical velocity (ascend) over Iraq as shown in Figure 9(d). The surface cyclone is filled and retreat eastward, Iraq become under influence of high-pressure system, and we can see convective precipitation just over Iran as in Figure 9(e).



Figure 10. (a, b, c, and d) surface temperature at 12 UTC for period 21-24 April 2018, the black solid contour line represents geopotential height at 500 hPa of interval 30 gpm, color shaded represent temperature at 1000 hPa in Celsius.

DISCUSSION

COL occurred due to the exchange process between stratosphere-troposphere in the upper troposphere. The exchange process intensified surface cyclone by enhancing convection processes at the surface in order to compensate the shortage of moisture at the upper troposphere which happened due to stratosphere intrusion. The onset of emergence COL (A) on 21 April at 12 UTC was over Mediterranean Sea and it was associated with strong high pressure system and cold temperature air on the surface compared to adjacent regions Figures 10(a, b, c and d) in which the high pressure system at the surface prevents any convection process could hasten the evolution process of COL (A).

Later on, it reached to the land over northern Africa on April 25 which coincided with the presence of the RST low system. Since RST is a tropical system loaded with warm and moist air, this system promoted convection process and accelerated evolution process of COL (A). At the same time the emergence of Omega block participated in prolongs the life of COL (A).





For SL-COL (B) case, since there is a tropical cyclone at the surface (Indian Monsoon) that loaded with humidity, the convection processes at the surface and the latent heat at the upper level were enhanced subsequently accelerating the decay process of COL (B).

CONCLUSION

Comparative study is made to diagnose the dynamical processes that participate in the stages of evolution and dissipation of COLs, and to find out the main processes that effect on life time of COLs. The reason behind LL-COL and SL-COL episodes at 12 UTC on April 21, and 12 UTC April 22 respectively was the high PV anomaly associated with the jet stream at 315 ° K isentropic surface as a result of stratospheric warm air intrusion at 150hPa. the reason behind the COL (A) and COL (B) dissipation at 18 UTC on April 30 and 12UTC on April 23 respectively was the latent heat that produced convective precipitation due to enhanced Surface convective processes by RST in case one and tropical monsoon in case two. The upper jet stream in two cases, causes drift the polar cold air at 500hPa equatorward. A trough with cold air at 500hPa deformed and separated from the main westerly flow as a COL system. In case one, LL- COL episode over water (Mediterranean Sea) with high pressure system and low temperature on the surface, which prevent any convection process and prolong life of COL (A) via stopped its evolution. On April 25, COL (A) system reaches north Africa, which an active RST deepen beneath it, convection processes reinforced with upper latent heat activate COL (A), Omega block formed on April 27 at 12 UTC, that prevents COL (A) from dissolved in spite of dissipation of high PV upper troposphere. As soon as Omega block dispend with retreating low-pressure systems at the surface, COL(A) would dissolve rapidly with persistence of convective process due to presence of surface tropical system. In summary there is many dynamical processes effect on life time of COLs, they exchange their roles through different pressure levels of troposphere, upper middle lower, then lower middle upper.

ACKNOWLEDGMENT

Acknowledgment is made for the use of ECMWEF's computing and archive facilities in this research.

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