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Determination Stability Potential Energy of Thunderstorms for Some Severe Weather Forecasting Cases In Baghdad City

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Abstract

CAPE or Convection potential energy available is the amount of fuel available for a developing thunderstorm. More specifically, it describes the instability of the atmosphere and provides an approximation of the strength of an upward current within a thunderstorm. Temperature data, Dewpoint, barometric pressure, and altitude were taken from satellites recorded by the European Altitude Center (32-26509.7) meters for atmospheric pressure levels (1000-20) bar, and the selection in hours (00:00 AM, 12:00 PM) For the special day 10 of the months (February, May, June, November) of the year 2018 over Baghdad Station (33.375 degrees North - 44.375 degrees East) Otherwise, was classified the clouds according to the cloud thickness and pressure levels as well as we studied the CAPE region in all clouds. CAPE values in the zero to 1,000 J/kg range are indicative of stable air masses this accompanies low stratus clouds and air masses with CAPE values in the (1,000-2,500) J/kg range are considered marginally to moderately unstable this accompanies medium clouds and may produce severe weather if other conditions (like orographic lifting or daytime. While values above 2,500 J/kg are considered to be very extremely

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unstable this accompanies Cumulonimbus clouds. The results showed that the CAPE area depends on the thickness of the cloud, cloud water content, saturated steam density and cloud location where thick clouds lead to higher CAPE during the average hour (00:00 AM and 12:00 PM).

Keywords: CAPE, Clouds, Dew point, Temperature, Baghdad.

1 Introduction

The potential convective potential energy is a measure of the convective potential in the atmosphere that includes both instability and moisture components. Climatology at CAPE provides valuable information for forecasting severe weather. CAPE can also be used as a potential indicator of climate change [1]. Variation in CAPE can also affect the temperature range in the upper troposphere [2][3]. For example, There many studies to find Forecasting of the CAPE by using the Synoptic study of the role of convective available potential energy on formation rainstorm over Iraq and resulted in the maximum values of the load potential energy are accompanied by the maximum convective precipitation values ranging from 500-400 j/kg to give precipitation between 1-2 mm/hr [4]. Some research showed that the absorbance and emissivity solar radiation by clouds, aerosols and some atmospheric gases and concluded that absorption, Emissivity and albedo by clouds, aerosols and gases depend on quantity, type, abundance, composition, location, atmospheric age, season, meteorological parameter (temperature, pressure, wind, relative humidity and precipitation) and wavelength. Where these factors play a very important role in terms of the amounts of cooling and heating (surface and atmosphere) at the times (00:00 AM, 12:00 PM) [5] [6] [7]. CAPE calculated assuming there the parcel ascends without mixing with the environment and adjusts instantaneously to the local environmental pressure. The momentum equation for such a parcel is (1), which can be rewritten following the vertical motion of the parcel as:

$$\frac{\mathrm{D}\omega}{\mathrm{Dt}} = \frac{\mathrm{Dz}}{\mathrm{Dt}}\frac{\mathrm{D}\omega}{\mathrm{Dz}} = \omega\frac{\mathrm{D}\omega}{\mathrm{Dz}} = \mathrm{b}' \qquad (1)$$

By division and multiplication by $\frac{Dz}{Dz}$ Where $b'(z)$ is again the buoyancy given by

$$b' = g\,\frac{(\rho\ env - \rho\ parcel)}{(\rho\ parcel)} = g\,\frac{(\rho\ env - \rho\ parcel)}{(\rho\ parcel)} \qquad (2)$$

Where T_{en} designates the temperature of the environment. If (1) is integrated vertically, ZLFC, to the level of neutral buoyancy, ZLNB, following the motion of the parcel the result is:

$$\frac{\omega 2\ max}{2} = \int_{Zf}^{Zn} g\left(\frac{T_{v,parcel} - T_{v,env}}{T_{v,env}}\right) dZ\ = B \qquad (3)$$

Here, B is the maximum kinetic energy per unit mass that a buoyant parcel that represents CAPE:

$$CAPE = \int_{Zf}^{Zn} g \left(\frac{T_{v,parcel} - T_{v,env}}{T_{v,env}} \right) dZ \qquad (4)$$

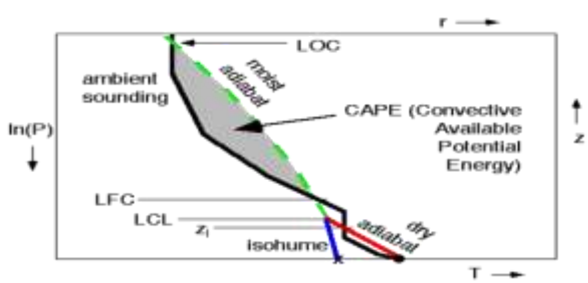
Where Zf is the rise in the level of free heat convection and Zn is the height of the equilibrium level, Tv, the part is the default specific ejection temperature (K̊), where Tv, env. Is the default environment temperature (K̊) and g is the acceleration due to gravity [8] [9].

2.1 Determining CAPE from Skew-T Plots

T-Φgram or Skew-T plots are used by meteorologists to help summarize current atmospheric conditions. A skew-T plot is a logarithmic graph of pressure versus temperature in the atmosphere at a given location. The data is collected from weather ECWMF that are released several times a day, and it is used to create Skew-T plots that can then be used to help meteorologists forecast the weather. CAPE for a given region is determined by looking for what is referred to as the positive area on a skew-T plot[10] [11]. The positive area represents the amount of energy gained by an air parcel when lifted (a positive addition of energy to the parcel) [12]. This can be found on a skew-T as the region above the level of free convection (LFC) and below the equilibrium level (EL) [13]. The LFC is where air masses can rise due to convection (positive movement), and the EL is where air masses begin to sink (negative movement) [14][15].

CAPE's opposing factor, convective inhibition (CIN), is determined by analyzing the negative area on the plot. CIN is a measure of the atmosphere's ability to resist an air parcel's ascent, while CAPE is a measure of an air parcel's available energy to rise [16]. CAPE and CIN can be used complementarily to forecast severe weather [17] point. The larger the calculated value of CAPE, the greater the odds are that the air parcel will rise and develop vertically and become some form of convective weather, like a thunderstorm or tornado [18].

CAPE is a measure of the air parcel's potential energy per kilogram of the air mass. In theory, the amount of potential energy a parcel can possess is unlimited, so it is possible for an unlimited CAPE value, and values above 8,000 J/kg have been recorded, see Figure 1 [19][20].



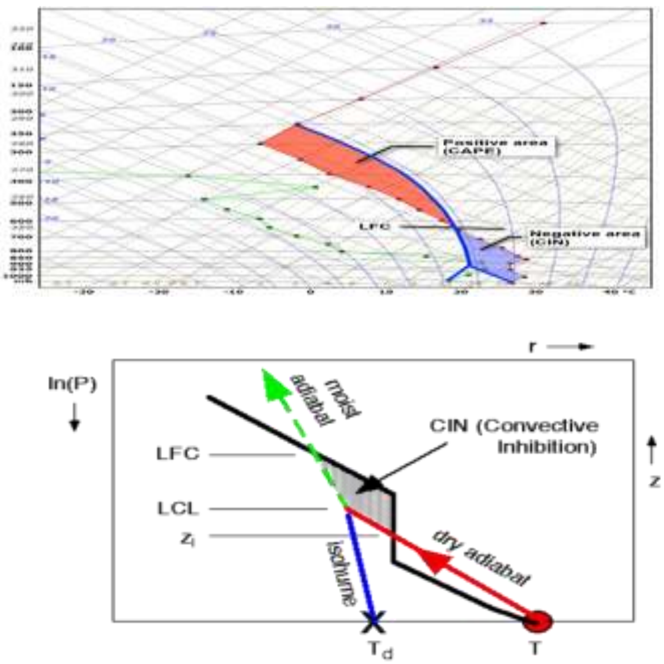


Figure 1 Determine the CAPE by Skew-T Plots scheme [21]**.**

2.2 Using CAPE to Forecast Severe Weather

CAPE values in the zero to 1,000 Joule range are indicative of stable air masses, or ones that don't possess enough energy to rise and become a convective weather system. Air masses with CAPE values in the 1,000 to 2,500 range are considered marginally to moderately unstable and may produce severe weather if other conditions (like orographic lifting or daytime[22]. Values above 2,500 are considered to be very to extremely unstable and are the air parcels most likely to produce severe weather, ranging from torrential rains to tornadoes [23] [24].

2.3 Data and Methodology

The work was carried out with an hourly average (temperature and dewpoint) for the days of 2018, taken from the European Center for Average Weather Forecasts specifically (ERA-Interim) model [25]. These data were taken during midnight and midday at the Baghdad station selected for this work, which is located at a latitude of 32.375 degrees north, longitude 44.375 degrees east, and a height of 31.7 m in central Iraq, as shown in Figure 2. The potential energy available for convection was calculated in all types of clouds. And the effect during the stable and unstable atmosphere 00: 00-12: 00 times [26] [27]. Thunderstorms were identified using sigmaplot.

Figure 2 Baghdad Station in Central Iraq map [28].

3 Results and Discussion

3.1 Determination the Points of Conv. and Div. for Cases Study

To determine the CAPE for day 10 for months (February, May, June, and November) of the year 2018 from the height of Conv. and diver. The points between temperature and dew point temperature, the vertical change curve that represents. Where if the temperature difference is less than 12 ° C then it represents the base of clouds, and if the temperature difference is greater than 12 ° C then it represents the top of the cloud, the thickness of the cloud was calculated during the study period and classified according to height and thickness During the year 2018 appeared many low, medium, and high clouds for each day in the year at the times 00:00 am and 12:00 pm. These clouds vary depending on meteorological parameters. To determine the CAPE for any layers. First, it needs to calculate the mean value of Eq. (4) for the layer. Second, divide the result by 2. Third, multiplying by (g), as shown Figures 3, 4, 5, and 6, and (Tables 1, and 2).

- During winter for the day 10 Feb 2018, A portion of the schematic sounding from the LFC (LCL) at 850 bar to the EL above the Tropopause at 150 bar. To determine the CAPE for a layer 850 bar to 150 bar. The thickness of the layer, in this case, equals 12551.1 m, which would yield a calculate of the mean CAPE for the layer. Where CAPE is equal 2599.69 J/kg for the day 10 Feb 2018, at hour 00:00 am.

Where this type of clouds are Low (Cumulusnimbus). The LFC (LCL) at 850 bar to the EL above the Tropopause at 125 bar. The thickness of the layer was 13774.9 m, where CAPE is equal to 2859.253 J/kg for the day 10 Feb 2018, at hour noon. This type of clouds are Low (Cumulusnimbus), see Figures 3.

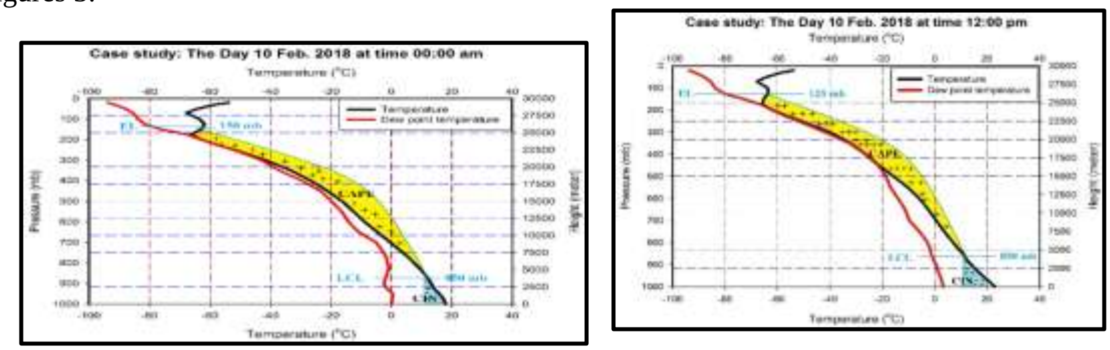


Figure 3 Determine CAPE from curved verticalchange of tempe., dewpoint, and regions of Conve. and Dive. for the day 10 Feb 2018, at the times 00:00 am and 12:00 pm over Baghdad station.

- During spring for the day 10 May 2018. The LFC (LCL) at 1000 bar to the EL above the Tropopause at 500 bar. To determine the CAPE for layers 1000 bar to 500 bar layer. The thickness layer, in this case, 5645.75 m, would yield a calculate of the mean CAPE for the layer. Where CAPE is equal to 1026.608 J/kg for the day 10 May 2018 at hour 00:00 am. This type of cloud is low (Cumulus). The LFC (LCL) at 1000 bar to the EL above the Tropopause at 600 bar. The thickness of the layer, in this case, 4242 m, calculate the mean CAPE for the layer. CAPE is equal to 749.2047 J/kg for the day 10 May 2018, at hour noon. This type of cloud is low (Cumulus), Figures 4.

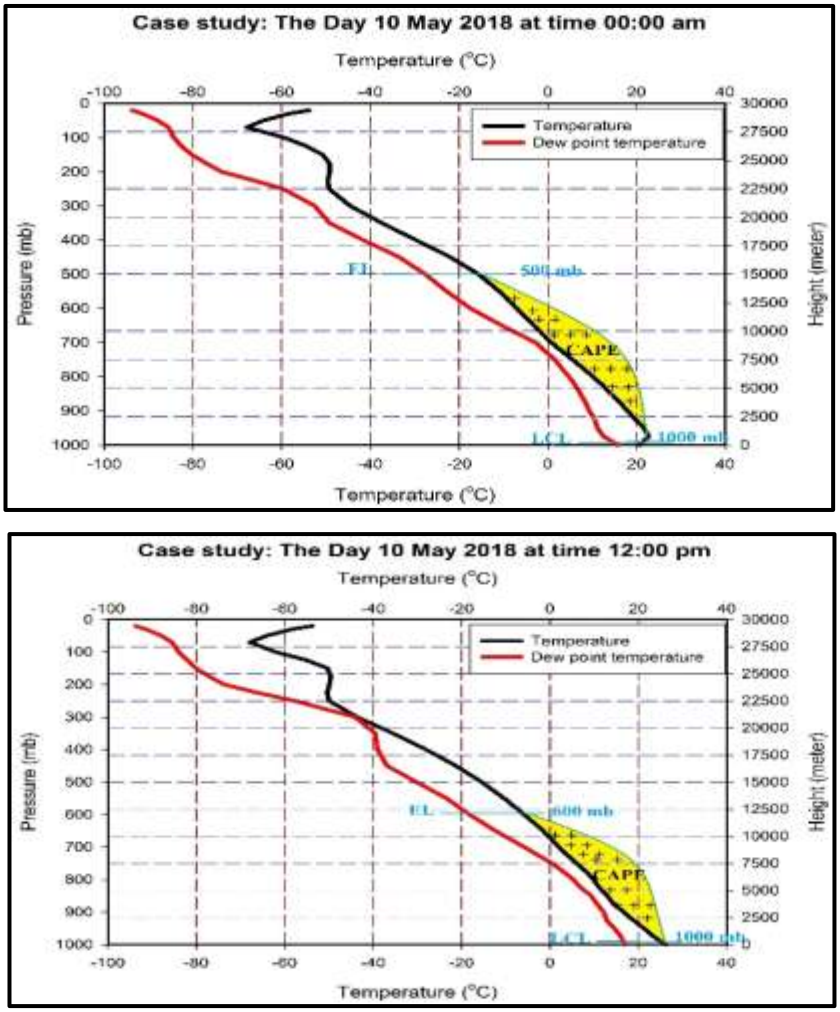


Figure 4 Determine CAPE from curved verticalchange of tempe., dewpoint, and regions of conve. and dive. for the day 10 May 2018 at the times 00:00 am and 12:00 pm over Baghdad station.

- During summer for the day 10 June 2018. The LFC (LCL) at 650 bar to the EL above the Tropopause at 600 bar. The thickness layer, in this case, 659.6 m, would yield a calculate of the mean CAPE for the layer. CAPE is equal to 119.3974 J/kg for the day 10 June 2018 at the hour 00:00 am. This type of cloud is medium (Ac). The LFC (LCL) at 100 bar to the EL above the Tropopause at 70 bar. The thickness of the layer, in this case, 2180.2 m, calculate the mean CAPE for the layer. CAPE is equal to 538.3656 J/kg for the day 10 June 2018 at the hour noon. This type of clouds are high (Cs), Figures 5.

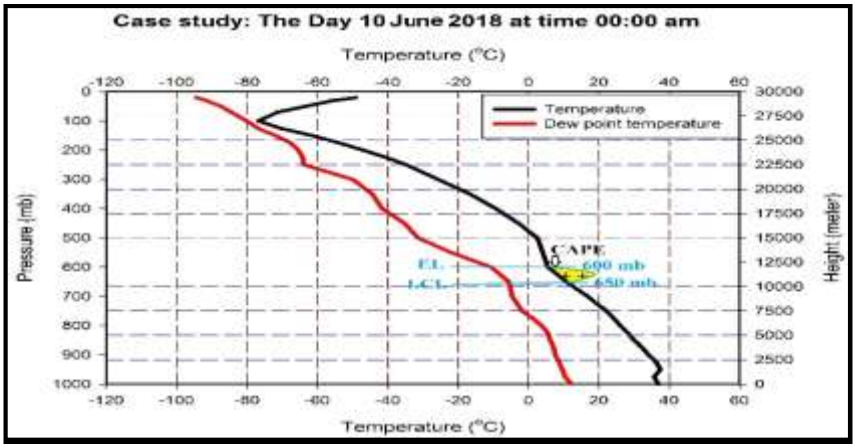
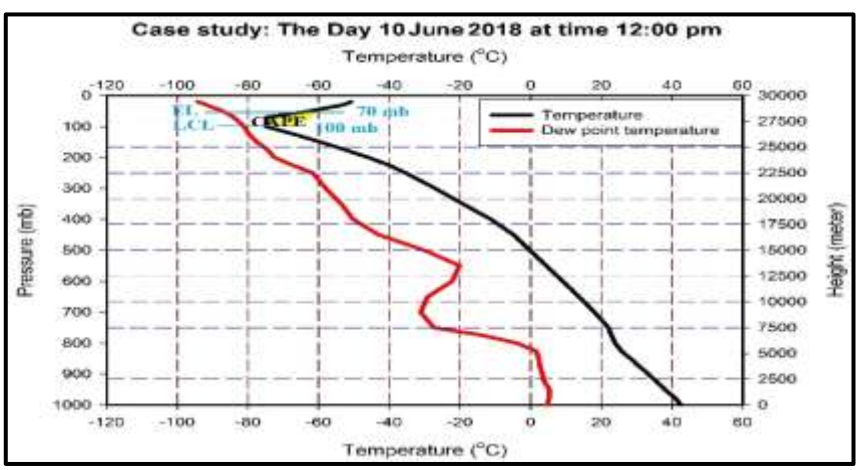


Figure 5 Determine CAPE from curved verticalchange of tempe., dewpoint, and regions of conve. and dive. for the day 10 June 2018 at the times 00:00 am and 12:00 pm over Baghdad station.

- During autumn for the day of 10 November 2018. The LFC (LCL) at 1000 bar to the EL at 900 bar. The thickness of the layer, in this case, 747.8 m, would yield a calculate of the mean CAPE for the layer. CAPE is equal to 129.1989 J/kg for the day 10 November 2018 at the hour noon. This type of clouds are low (St). The LFC (LCL) at 775 bar to the EL above the Tropopause at 650 bar. Thickness layer, in this case, 1396 m, the mean CAPE for the layer. CAPE is equal to 254.5057 J/kg for the day 10 November 2018 at the hour 00:00 am. Where this type of clouds are Medium (Ac). The LFC (LCL) at 850 bar to the EL at 700 bar. The thickness of the layer, in this case, 1843.85 m, calculate the mean CAPE for the layer. CAPE is equal to 330.5056 J/kg for the day 10 November 2018 at the hour noon. This type of clouds are Lows (Sc) Figures 6.



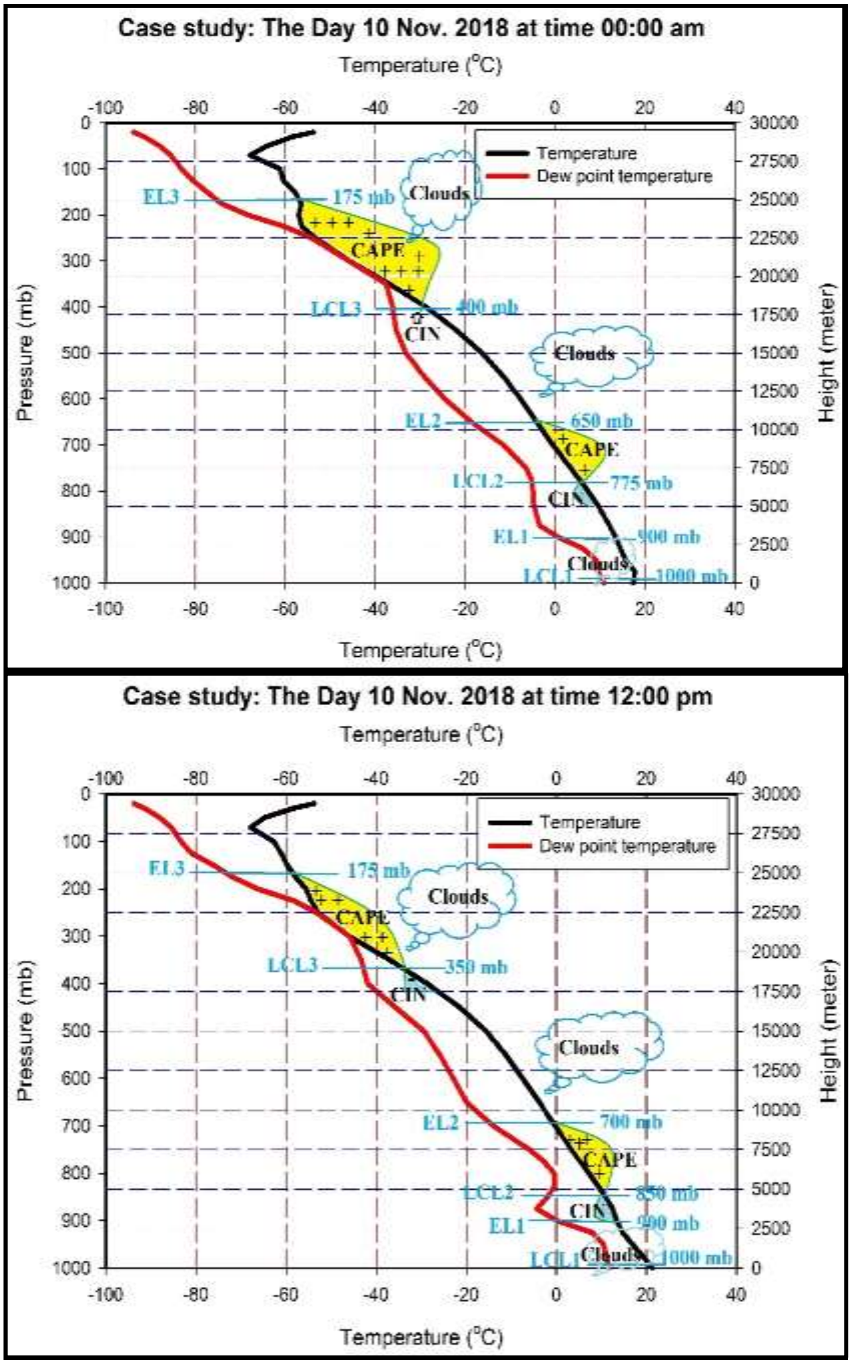


Figure 6 Determination of the CAPE of the vertical curvedchange of tempe., dewpoint, and areas of conve. and dive. for November 10, 2018, at the times 00:00 am and 12:00 pm above Baghdad station.

Table 1 T-Φ gram model application results by determining of conve. and dive. region between the two curves of the vertical change of tempe. and dewpoint at midnight for the characteristic day for the year 2018 over Baghdad city.

Month /Day	P(MB) at point Conv.	Z(m) at point Conv.	T(ºC) at point Conv.	Td(ºC) at point Conv.	P(MB) at point Div.	Z(m) at point Div.	T(ºC) at point Div.	Td(ºC) at point Div.	Z (km)	Cloud type
At the time 00:00 am										
12/10	1000	32	15.98	12.31	350	8307.7	-34.53	-51.02	8.3	Cb
12/25	1000	32	14.07	4.42	800	1864.65	0.72	-11.47	1.8	Sc
12/25	500	5677.75	-19.62	-30.40	450	6446.5	-25.25	-43.59	0.7	Ac
12/25	225	11220.7	-57.31	-68.99	150	13761.9	-63.61	-75.80	2.5	Cs
1/10	925	573.5	10.47	-1.00	900	779.8	8.78	-4.91	0.2	St
1/10	600	4274	-10.30	-21.15	175	12793.15	-56.77	-74.04	8.5	Ns
1/25	1000	32	16.06	4.85	700	3054.65	-1.95	-13.94	3.0	Cu
2/10	850	1210.8	10.81	-1.34	150	13761.9	-62.79	-76.16	12.5	Cb
2/25	1000	32	12.66	9.71	700	3054.65	-1.51	-17.70	3.02	Cu
3/10	900	779.8	12.66	1.88	775	2218.4	3.88	-8.63	1.4	Sc
3/10	450	6446.5	-22.87	-32.67	175	12793.15	-60.38	-74.54	6.3	Ci
3/25	650	3614.4	4.36	-5.52	150	13761.9	-62.22	-78.02	10.1	Ns
4/10	775	2218.4	9.31	-0.01	400	7381.8	-27.69	-42.03	5.1	As
4/10	250	10561.3	-52.08	-63.98	225	11220.7	-54.65	-67.41	0.6	Cs
4/25	900	779.8	16.73	4.75	850	1210.8	12.87	0.29	0.4	St
4/25	300	9343.55	-42.82	-49.58	175	12793.15	-57.34	-70.32	3.4	Ci
5/10	1000	32	20.70	15.84	500	5677.75	-15.62	-27.63	5.6	Cu
5/10	450	6446.5	-21.98	-33.50	225	11220.7	-49.61	-66.44	4.7	Ci
5/25	800	1864.65	17.02	6.30	550	4948.45	-6.17	-27.06	3.0	Cu
5/25	350	8307.7	-29.97	-40.12	225	11220.7	-51.09	-63.87	2.9	Ci
6/10	650	3614.4	4.51	-7.25	600	4274	0.61	-20.79	0.6	Ac
6/25	125	14985.7	-69.12	-79.22	50	20585.9	-64.77	-87.03	5.6	Ci
7/10	150	13761.9	-61.51	-71.87	70	18561.65	-71.33	-84.44	4.8	Ci
7/25	125	14985.7	-68.06	-74.07	50	20585.9	-65.26	-87.08	5.6	Ci
8/10	250	10561.3	-36.99	-45.12	70	18561.65	-69.36	-84.58	8.0	Ci
8/25	150	13761.9	-62.43	-73.85	70	18561.65	-71.75	-84.03	4.8	Ci
9/10	125	14985.7	-68.63	-79.12	70	18561.65	-67.28	-85.00	3.6	Ci
9/25	125	14985.7	-66.95	-78.10	70	18561.65	-67.39	-85.17	3.6	Ci
10/10	1000	32	23.35	17.50	400	7381.8	-23.40	-35.73	7.3	Cb
10/10	350	8307.7	-30.97	-42.15	150	13761.9	-61.65	-74.01	5.4	Ci
10/25	1000	32	23.35	17.50	400	7381.8	-23.40	-35.73	7.3	Cb
10/25	350	8307.7	-30.97	-42.15	150	13761.9	-61.65	-74.01	5.4	Ci
11/10	1000	32	17.49	10.80	900	779.8	13.46	0.64	0.7	St
11/10	775	2218.4	5.43	-5.24	650	3614.4	-4.02	-18.58	1.4	Ac
11/10	400	7381.8	-28.66	-36.11	175	12793.15	-56.43	-74.24	5.4	Ci
11/25	1000	32	15.21	14.78	225	11220.7	-51.73	-68.70	11.1	Cb

Table 2 Results of applying T- Φ gram model by determining the area of Conve. and Dive. between the verticalchange in Tempe. curve and the Dewpoint at midday for the special day of 2018 over the city of Baghdad.

Month /Day	P(MB) at point Conv.	Z(m) at point Conv.	T(°C) at point Conv.	Td(°C) at point Conv.	P(MB) at point Div.	Z(m) at point Div.	T(°C) at point Div.	Td(°C) at point Div.	Z (km)	Cloud type
At the time 12:00 pm										
12/10	1000	32	17.31	9.80	300	9343.55	-42.81	-60.63	9.3	Cb
12/25	1000	32	13.95	9.26	825	1586.8	3.19	-11.49	1.5	Sc
12/25	250	10561.3	-51.75	-63.76	100	16381.45	-68.99	-82.88	5.8	Ci
1/10	950	381.7	12.53	1.16	875	986.1	7.85	-10.23	0.6	St
1/10	250	10561.3	-54.47	-65.50	175	12793.15	-58.99	-72.41	2.2	Cs
1/25	975	209.5	18.87	7.55	550	4948.45	-14.97	-33.65	4.7	Cb
2/10	850	1210.8	10.65	-1.34	125	14985.7	-63.46	-80.50	13.8	Cb
2/25	1000	32	17.52	7.06	650	3614.4	-8.41	-22.57	3.6	Cu
2/25	450	6446.5	-26.16	-35.89	225	11220.7	-51.54	-68.48	4.8	Ci
3/10	900	779.8	12.79	2.22	825	1586.8	7.04	-8.87	0.8	St
3/10	500	5677.75	-17.67	-29.10	200	11946.95	-58.02	-70.67	6.2	Ci
3/25	925	573.5	19.07	7.52	150	13761.9	-62.13	-77.26	13.1	Cb
4/10	950	381.7	23.54	13.19	600	4274	-5.05	-18.60	3.9	Cu
4/10	300	9343.55	-44.11	-53.19	175	12793.15	-58.22	-74.37	3.4	Ci
4/25	850	1210.8	14.82	3.75	800	1864.65	11.46	-2.40	0.6	St
4/25	350	8307.7	-35.53	-38.55	175	12793.15	-54.92	-72.28	4.5	Ci
5/10	1000	32	26.18	16.95	600	4274	-5.77	-18.17	4.2	Cu
5/10	400	7381.8	-27.99	-38.97	225	11220.7	-50.36	-66.29	3.8	Ci
5/25	825	1586.8	18.40	8.49	600	4274	0.13	-24.30	2.7	Cu
6/10	100	16381.45	-70.25	-82.82	70	18561.65	-69.18	-85.13	2.2	Cs
6/25	125	14985.7	-70.53	-78.72	50	20585.9	-63.63	-87.34	5.6	Ci
7/10	100	16381.45	-74.93	-81.08	50	20585.9	-62.37	-87.19	4.2	Ci
7/25	700	3054.65	13.28	2.74	600	4274	5.79	-8.41	1.2	Ac
7/25	150	13761.9	-59.53	-71.32	70	18561.65	-68.61	-84.29	4.8	Ci
8/10	300	9343.55	-26.80	-39.00	70	18561.65	-68.61	-84.29	9.2	Ci
8/25	200	11946.95	-49.03	-59.13	50	20585.9	-62.19	-87.31	8.6	Ci
9/10	125	14985.7	-68.17	-79.20	70	18561.65	-66.85	-85.03	3.6	Ci
9/25	100	16381.45	-70.64	-81.50	70	18561.65	-67.16	-84.94	2.2	Cs
10/10	700	3054.65	8.88	-1.49	150	13761.9	-59.87	-74.04	10.7	Ns
10/25	975	209.5	24.67	13.77	125	14985.7	-62.92	-79.36	14.8	Cb
11/10	1000	32	21.37	11.64	900	779.8	13.41	0.14	0.7	St
11/10	850	1210.8	10.94	-1.98	700	3054.65	-0.28	-14.00	1.8	Sc
11/10	350	8307.7	-36.92	-43.30	175	12793.15	-57.92	-71.92	4.5	Ci
11/25	1000	32	17.15	11.50	250	10561.3	-48.86	-68.83	10.5	Cb

3 Conclusions

- Baghdad is characterized by a lack of rainfall and limited to winter mainly and the beginning of spring and autumn less degree.
- Where low, medium, and high clouds appeared during the winter, spring, and autumn seasons.
- The thick clouds have the highest Convective Available Potential Energy from thin clouds.
- The cumulonimbus clouds having CAPE equal to 2599.69 J/kg for 2018/2/10-00:00 and CAPE is equal to 2859.253 J/kg for 2018/2/10-12:00.
- The low cumulus clouds having CAPE equal 1026.608 J/kg for 2018/5/10-00:00 and CAPE equal 749.2047 J/kg for 2018/5/10-12:00.
- The medium Altocumulus clouds having CAPE equal 119.3974 J/kg for 2018/6/10-00:00and CAPE is equal to 538.3656 J/kg for2018/6/10-12:00 the clouds type was (Cs).
- The low Stratus clouds having CAPE equal 129.1989 J/kg for 2018/11/10-00:00 and 12:00. The medium Altocumulus clouds having CAPE equal 254.5057 J/kg for 2018/11/10-00:00.
- The low Stratocumulus clouds having CAPE equal 330.5056 J/kg for 2018/11/10-12:00.
- CAPE values in the zero to 1,000 Joule range are indicative of stable air masses, and Air masses with CAPE values in the 1,000 to 2,500 range are considered marginally to moderately unstable, while values above 2,500 are considered to be very to extremely unstable.

Nomenclatures

mbar	Millibars is Atmospheric pressure unit, equal to 100 Pascal's (1,013.25 hPa = 1,013.25 mbar)
CAPE	Convective Available Potential Energy
ECMWF	European Centre for Medium-Range Weather Forecasts
LFC	Level of Free Convection
FCL	Free Convective Layer
EL	Equilibrium Level
CIN	Convective Inhibition
ERA	ECMWF Re-Analysis
PBE	Positive Buoyant Energy
PBL	Planetary Boundary Layer
LCL	Lifting Condensation Level
g	Gravitational acceleration is approximately 9.81 m/sec^2

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