ANALYTICAL STUDY OF RATE VOLUME LIQUID WATER CONTENT IN LOW CLOUDS OVER IRAQ

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ABSTRACT

Iraq suffers a severe declining catastrophic in water resources; due to disagreement Share water to the neighboring countries Turkey, Syria and Iran. As well as the water policy in Iraq is unclear, the management of Iraq water have no strategic plan to treat the severe decrease in water sources. In this study, adopted eight climatic stations, are available at Iraqi general meteorological organization. The low clouds data 24 observations per day had been taken, from 1975 to 2005. For this purpose, the researchers determined the distribution of the stations and water amount at the Iraq using (GIS) Technique. It has found the annual average liquid water content calculated from the Low cloud only is 2585742648 m^3, and the annual average Rainfall from the low cloud is 2563537 m^3. In addition, the net LWC is 2583179111 m^3, so there are great opportunities to Enhancement rain from Low Clouds. To get the greatest benefit from the main low – level clouds in supplying liquid water for cloud seeding, must be given a serious attention to observing four clouds type (Sc5, Cb9, Sc8 and Cu2).

Keyword: GIS, water resources,seeding.

دراسة تحليلية لمعدل الحجم السنوي للحمولة المائية في الغيوم الواطئة فوق العراق

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المستخلص

يعاني العراق من تدهور حاد يمكن أن نسميه كارثيا في الموارد المائية بسبب الخلاف على تقاسم المياه مع دول الجوار تركيا وسوريا وإيران. فضلا عن عدم وضوح السياسة المائية في العراق. اذ لا تملك إدارات المياه العراقية خطة استراتيجية لمعالجة الانخفاض الحاد في مصادر المياه . اعتمد الباحثون في هذه الدراسة ثماني محطات مناخية متوفرة في هيئة الأرصاد الجوية العراقية. وقد تم الحصول على بيانات الغيوم الواطئة من خلال 24 رصدة يوميا خلال المدة الزمنية مابين (1975 إلى 2005)، لهذا الغرض حدد الباحثون توزيع المحطات وكمية المياه في العراق باستخدام تقنية (GIS). ووجدت الدراسة أن متوسط الحجم السنوي لسوائل الماء المحسوب من الغيمة الواطئة فقط هو[2585742648 م^3]، والمتوسط السنوي لهطول الأمطار من سحابة منخفضة [2563537 م^3]. ويبلغ الصافي المحتوى المائي LWC [2583179111 م^3]، لذلك هناك فرص كبيرة لتحسين المطر من السحب المنخفضة وللحصول على أكبر فائدة من السحب الرئيسية منخفضة المستوى في توفير المياه السائلة من استمطار الغيوم الواطئة ، يجب إيلاء اهتمام جاد لملاحظة أربعة أنواع من تلك الغيوم وهي (Sc5 و Cb9 و Sc8 و Cu2).

الكلمات المفتاحية : GIS , الموارد المائية, الاستمطار .

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INTRODUCTION

Climate studies passed more than one stage, the first stage is a description, the second to the analysis and the third stage is treatment, Climate studies recently start to invest elements of climate in application studies, such as investment wind energy, solar energy get and the benefit from the rain. Water is an indispensable source for all life forms and it is the natural resource for sustainable development (21). In addition, it is very important for all human activities in terms of social, economic, and health of ecosystems. When water is available, economic chance could be enhanced. Therefore, in the absence of water there will be obstacles to growth (13, 22). Clouds classified according to their water content as well as the origin of the cloud, as the water content of the cloud depends greatly on its type and height in the atmosphere (3,21). In addition, Cloud liquid water path (LWP) decrease with increasing cloud temperature (13). Liquid water content, cloud base altitudes, and, droplet size distribution an important parameter to study the relationship between liquid water content LWC and cloud droplet number concentration, Cloud volume, as well, chemistry monitoring and cloud physical measurement (10,18). LWC shows a prominent seasonal variation. Therefore, it is distributions characterized associated with cloud phase, cloud type, precipitation fortuity, and geolocation (13, 15). For instance, S.-B. Oh et al, (16) have estimated liquid water content (LWC), and the reflectivity–liquid water content (Z–LWC) relationships were derived using the vertical profiles of radar reflectivity and the liquid water path (LWP) from a microwave radiometer. However, many studies have given positive reports regarding estimating and calculating the water content of clouds in various studies, including the possibility of investing it in the cloud seeding process (3, 11, 12, 14,17, 20). This study considered part of the investment of climate elements, which called the economic climate. By investing water, in the low clouds, using the cloud seeding process. Stations were selected (Mosul, Kirkuk) in the north part of Iraq, (Rutba) in the west part of Iraq, (Al Hai) in the east part, (Baghdad and Diwaniya) in the middle part, and (Al-Nasiriyah and Basrah) in the south part of Iraq. This study is part of the investment of climate elements, which called the economic climate. Through investing water in the low clouds by cloud seeding, process (6). Because, low clouds possess huge quantities of water, if invested optimally, it will reduce the risks of decreased quantities of water in the Tigris and Euphrates rivers, which constitute a threat to the environment in Iraq on the one hand, and will eliminate the encroachment of the desert and the dust storms that occurred in Iraq on the other hand. That is result of rain enhancement. An analytical method used in this study and clarify the attributes set out stations, also regional approach uses to determine the spatial and temporal variation of the characteristics of the data. When relative humidity reaches 100 percent, the air becomes saturated and water vapor begins to condense into droplets. The dust provides nuclei that contribute to their condensation (7). At ground level, mist or fog forms, above the ground level, water condenses and clouds start to appear. Low clouds are mostly composed of water droplets since their bases generally lie below 6,500 feet (2,000m). When temperatures are cold, enough, these clouds may also contain ice particles and snow objectives (18, 22). This study was aimed the possibility of analyzing the attributes one of the climatic phenomena, in terms of recurrence, and the annual average volume of liquid water in each type of low clouds over selected stations in Iraq.

MATERIALS AND METHODS

Study Area

Iraq is located between 29° 05` - 37° 23` North and 38° 45` - 48° 45` within tropical regions in the northern hemisphere of earth (1) east of Greenwich line between longitudes (38.45°-48.45°) and north of the equator between latitudes (29.5°-37.5°) system ==Similar to that of the Mediterranean (10, 5). the total area of Iraq is 438320 km^2 and located in south-west of the Asian continent and northeast of the Arabian Peninsula. From the north, northeast and east is surrounding by mountains, which can reach altitudes of 3550 m above sea level. Iraq has a plateau in the eastern part and there is a sedimentary plain between it and the mountains (5). Table (1) shows all stations indicate the features of Iraq weather affected by the sub-tropical climate, specifically the province Arid and semi-arid zones of the Mediterranean climate, according to Koppen classification climate (8).

Table 1. Geographical information of the stations (4)

station	Station Number	Elevation (mater)	Latitude (degree)	Longitude (degree)
Al-Mosul	**608**	**223**	**36° 32´**	**43° 15´**
Kirkuk	**621**	**331**	**35° 47´**	**44° 40´**
Al-Rutba	**642**	**630.8**	**33° 03´**	**40° 28´**
Baghdad	**650**	**31.7**	**33° 23´**	**44° 23´**
Al-Hai	**665**	**17**	**32° 17´**	**46° 05´**
Al-Diwaniyah	**672**	**20**	**31° 98´**	**44° 98´**
Al-Nasiriya	**676**	**7.6**	**31° 08´**	**46° 23´**
Al-Basrah	**689**	**2.4**	**30° 57´**	**47° 78´**

Iraqi climate characterized by being hot dry summers, cool to Moderate in winter. Which can be divided into four main regions: steppes with winter rainfall, the desert zone with extreme summer temperatures, and the irrigated area, this extends between the Tigris and Euphrates rivers from the north of Baghdad to Basra in the south (2, 9). Looking at the elevation of the studied stations, the Al-Rutba is the highest station (630.8 m) above sea level, Al-Mosul and Kirkuk between (200 – 330 m), and the rest of stations are less than 50 meters. The locations of the eight stations clear in figure 1. (8).

Figure 1. location of the climatic studied stations

RESULTS AND DISCUSSION

In the literature, the frequency of clouds calculated statistically using Excel program, and the following equations adopted in calculating the liquid water content of the clouds (19, 21). The droplet concentration of a cloud is the number of water droplets in a volume of cloud, typically a cubic centimeter (21). The formula for the droplet concentration is as follows:

$$n = N \ /V \quad \text{------------} \quad (1)$$

Where, N Indicate the total number of water droplets in the volume and V represent total the volume of the cloud. Converting this to a LWC gives an equation which shown below.

$$\mathbf{LWC= (m_w * n) / N \text{ -------------} (2)}$$

Where, m_w represents the mass of the water in the air parcel. Determining LWC is calculation in equation (3) as shown below (19).

$$\mathbf{LWC = mw / Vc \text{ ------------------} (3)}$$

Mw is the mass of the water in the cloud chamber and Vc is the volume of the cloud chamber. To Calculated the mass of the liquid water in the cloud chamber, which involving the latent heat of condensation, from using equation (4), (19).

$$\mathbf{mw = - ma. cp. \Delta T / Lc (T) \text{ ------} (4)}$$

In equation (4), Lc (T) latent heat of condensation of water at temperature T, m_a is the mass of the air in the cloud chamber; c_p is the specific heat of dry air at constant pressure and ΔT is the change in the temperature of the air due to latent heat. Table (2), shows the average annual of the period for all types of Low clouds for the thirty years from 1975 end to 2005 [4653 cloud per year]. It can be seen that the Stratocumulus clouds (Sc5); the most repeat over Iraq is 1488 times per year, so the percentage of a repeat Sc5 clouds is 32.85%. The annual repetition rate of broken cumulus stratified stratocumulus (Sc8) is [836] times per year, so the percentage of repeat of Sc8 clouds is 18.42%. The cumulus convective cloud (Cu1) rate of repeat annual is 821 times per year and percentage of recurrence of Cu1 clouds is 19.28%. And Cumulonimbus clouds thunderstorms (Cb9) is [618] times per year, and Cb9 clouds is 13.3%. The annual repetition rate of cumulus clouds convective cumulus (Cu2) [445] times per year the percentage of a repeat of (Cu2) clouds is 9.75%, and Cumulonimbus clouds thunderstorms (Cb9) is [618] times per year and Cb9 clouds is 9.79%. =It has been provided by experience Cloud Seeding that success rates Enhancement of Rain from 5% to 20% of clouds class (St). In addition, success rates cumulus clouds (Cu) up to 100%, and rain enhancement experiments have proven that guaranteed success of Cumulonimbus clouds thunderstorms (Cb9). Table (2) shows the distribution of total clouds. In addition, that there is very good chance to success cloud seeding**.**

Table 2. The rate annual total period all types for low clouds over Iraq through period 1975-2005

Station	Cu1	Cu2	Cb3	Sc4	Sc5	St6	Fs7	Sc8	Cb9	Total
Mosul	162	68	10	61	242	31	33	168	68	843
Kirkuk	142	52	04	06	194	83	31	162	33	707
Baghdad	109	47	08	11	211	10	08	152	210	766
Rutba	39	72	09	12	259	20	10	134	29	584
Al-Hai	63	85	01	02	106	01	02	34	28	322
Diwaniyah	99	36	02	08	223	10	09	44	19	450
Nasiriya	72	28	03	04	117	07	08	26	39	304
Basrah	135	57	03	05	136	23	10	116	192	677
Total	821	445	40	109	1488	185	111	836	618	4653

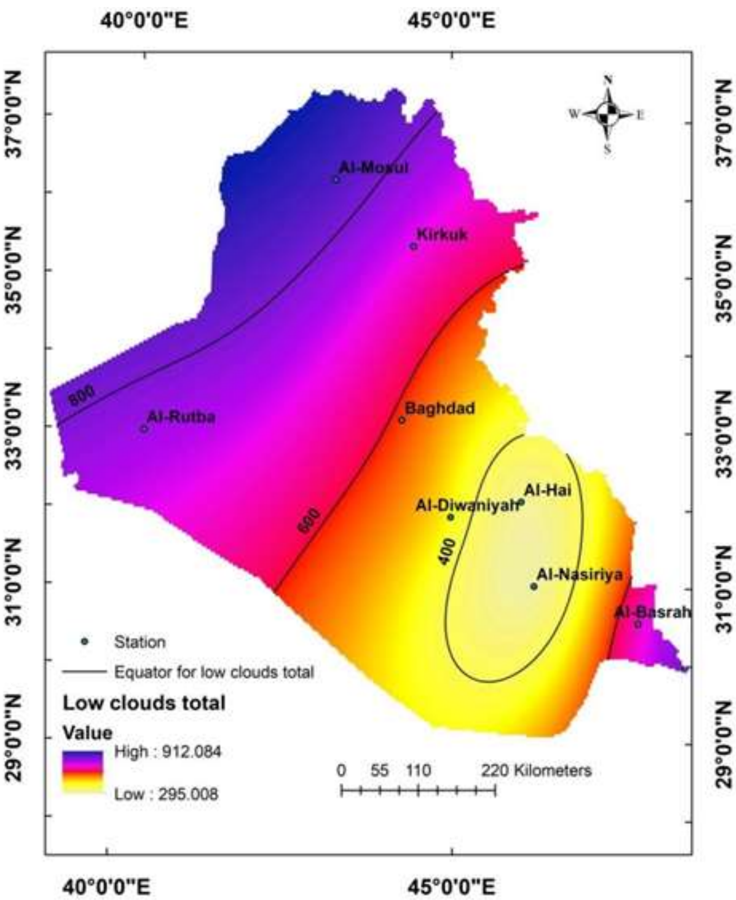

Figure 2. shows the distribution of total cloud in Iraq

Table (3) shows the types of low clouds and annual average liquid water contains (LWC) over stations. The total annual average of LWC over all stations is [2585742648 m^3]. Analyzing table (3) data, the Sc5 is the more type has been repeated at the study period [1488] this type if depend on the recurrence; it will be the first rank with a percentage 32 %. The second rank is Cb9 has been repeated 618 with a ratio 13 %. But from table (4), and comparing between the Sc5 and Cb9, the Cb9 value is [1910376 m^3], and (Sc5) value is [615840 m^3]. Therefore, the Cb9 more benefit comparing with (Sc5). When analyzing comparing the contributing share of the clouds, the (Sc5) comes to be at the first rank, because this type gives about [916369920 m^3], when (Cb9) gives an average annual amount reaches to [1180612368 m^3], as an explanation Figure (3) shows the distribution of the cloud, when taking number of recurrences.

Table 3. The total low cloud liquid water content for each type throw studied period

station	Kirkuk	Al-Hai	Basrah	Mosul	Baghdad	Diawanah	Nasiriya	Rutba	8 stations
Cu1	11629800	5159700	11056500	13267800	8927100	8108100	5896800	3194100	67239900
Cu2	25471680	41636400	27920880	33309120	23022480	17634240	13715520	35268480	217978800
Cb3	2743104	685776	2057328	6857760	5486208	1371552	2057328	6171984	27431040
Sc4	6486480	360360	900900	10990980	1981980	1441440	720720	2162160	25045020
Sc5	119472960	65279040	83754240	149033280	129942240	137332320	72053280	159502560	916369920
St6	5577600	67200	1545600	2083200	672000	672000	470400	1344000	12432000
Fs7	3906000	252000	1260000	4158000	1008000	1134000	1008000	1260000	13986000
Sc8	24154200	5069400	17295600	25048800	22663200	6560400	3876600	19979400	124647600
Cb9	63042408	53490528	366792192	129905568	401178960	36297144	74504664	55400904	1180612368
Total average annual LWC (m3)	262484232	172000404	512583240	374654508	594882168	21051196	174303312	284283588	2585742648

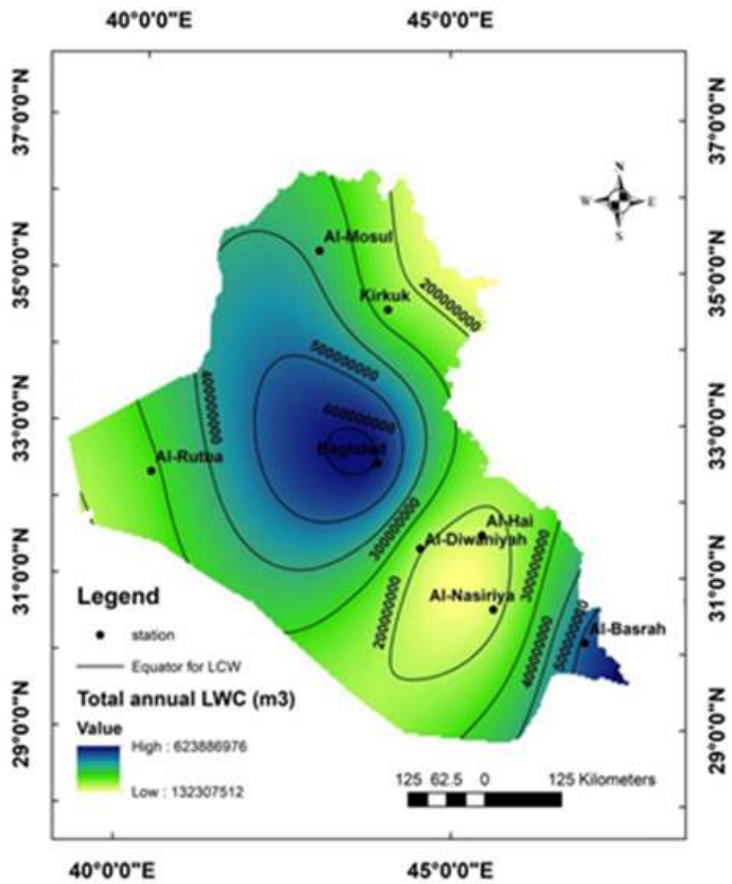

Figure 3. distribution of the cloud total amount water content (LWC)

All types of low clouds over Iraq during the period shown in Table (4). Annual mean total volume of water of all types of low clouds is [2585742648 m^3], and the mean annual rainfall in eight Iraqi stations climatic [2563537 m^3], while the mean annual rainfall in eight Iraqi stations climatic [2563537 m^3], and the percentage of rainfall from the total annual average water volume in all types of clouds is [0.0992 %]. Table (4) also contains the size of water content in each type of clouds for example, Cumulonimbus clouds thunderstorms type Cb9 (LWC) have [1910376 m^3] water content in one cloud. In addition, it has an annual average frequency [618] times per year, so the Annual average volumes of their water content is [1180612368 m^3], flaking rain is [574911 m^3], So the volume of water that cb9 cloud in the atmosphere [1180037457 m^3]. Table (4) illustrates the huge amount of water remaining from low clouds in the atmosphere that passes annually over Iraq, only. It should be note that there are large quantities of water in medium clouds, which are add to the annual recurring average of low clouds, which is shown in figure (4).

Table 4. the repeat for each type of low clouds over Iraq and the volume of LWC, the rainfall, and the net volume of LCW rest in each type of cloud

Type of cloud	Volume of LWC per one cloud (m^3)	Annual rate of LWC (m^3)	Average annual rainfall (m^3)	Net volume average annual (LWC)
Cu1	81900	67239900	147654	67092246
Cu2	489840	217978800	69115	217909685
Cb3	685776	27431040	12566	27418474
Sc4	180180	25045020	43982	25001038
Sc5	615840	916369920	408407	915961513
St6	67200	12432000	477522	11954478
Fs7	126000	13986000	292168	13693832
Sc7	149100	124647600	537212	124110388
Cb9	1910376	1180612368	574911	1180037457
Total	4306212	2585742648	2563537	2583179111

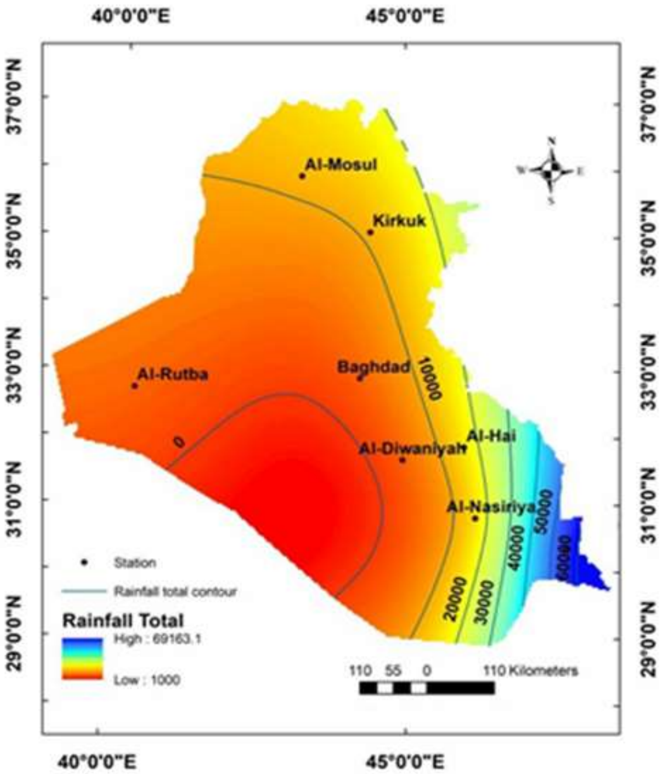

Figure 4. shows water from medium clouds added to the annual average repeated from low clouds

Figure (5) shows, the possibility of arranging the withdrawal according to the average annual amount of water content, as mentioned in Table (3). When examine clouds in terms of frequency can see the cloud (Sc5) type have more repeated [194] times at Kirkuk station, during the study. It's takes first rank with percentage of [27.4 %], white at the second rank can see cloud (Sc8) type which is repeated [162] times with percentage of about [23.2%], as mentioned in the figure (2). While, when examining the types of clouds, depending on the amount of maximal of it, as mentioned in table (4) comes from cloud (Cb9) type with about [1180612368 m3], and cloud (Sc5) type at the second rank with About [916369920 m^3]. At make another pattern comparison using the average annual amount at Kirkuk station, can see that (Sc5) type is about [119472960 m^3], and percentage of this contribute reaches to (45.52%). While (Cb9) type comes at the second rank in amount about [63042408 m^3], with percentage reaches to (24%). Whereas, at the last rank can see the (Fs7) with about [3906000 m^3], with percentage contribute reaches to (1.5%). It is clear that the biggest amount of liquid water can get it from (Sc5). Therefore, accordingly this analysis, the share of supplies for any type of low-level cloud can be arranged according to amount of rain in Kirkuk station. This conclusion applies to the Mosul station as shown in Table (5) and figure (6). Based on the above, there are very clear differences between clouds in the amounts of liquid water content they carried. Can be determined easily the amount of water that can be offered by each cloud separately in each station of the study from the following figures. Figure (5), shown that (Cb9, Sc5,) gives the greatest amount of liquid water, and somewhat (Sc8, Cu2, Cu1) in the second rank at each one of (Al-Mosul, Kirkuk, Baghdad and Al-Rutba) stations.

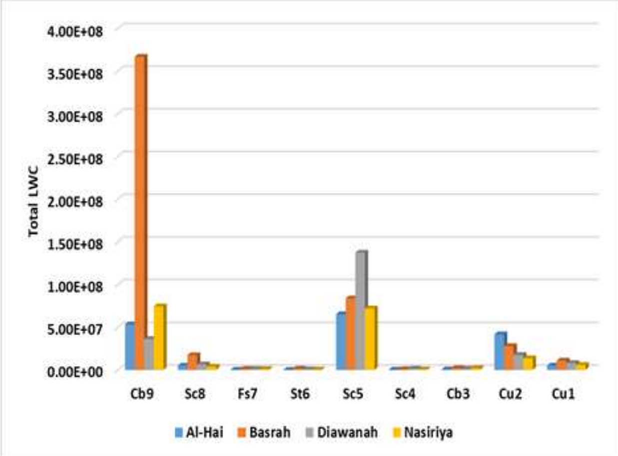

Figure 5. Shows the attributing of each cloud at four indicated stations

Just cloud (Cb9) type can supply about [129905568 m^3] of liquid water per year, at Al-Mosul station, and about [401178960 m^3] of liquid water per year, at Baghdad station. Thus, to make any project for cloud seeding and making artificial rain should be invested these two types of clouds, and waiting for their appearance or coming. (Sc8 and Cu2) comes after (Cb9) at the importance. The other types of clouds come less, so must be give a serious attention to observing (Sc5, Cb9, Sc8 and Cu2) type to get the greatest benefit, followed in figure (5). When analyzing the effect of the low-level clouds, figure (6) shows that (Cb9 and Sc5) taking the first rank at supplying liquid water at each of (Al-Hai, Diwaniyah, Al- Nasiriyah and Basrah). Place at supplying liquid water to each of (Al-Hai, Diwaniyah, Al-Nasiriyah and Basrah).

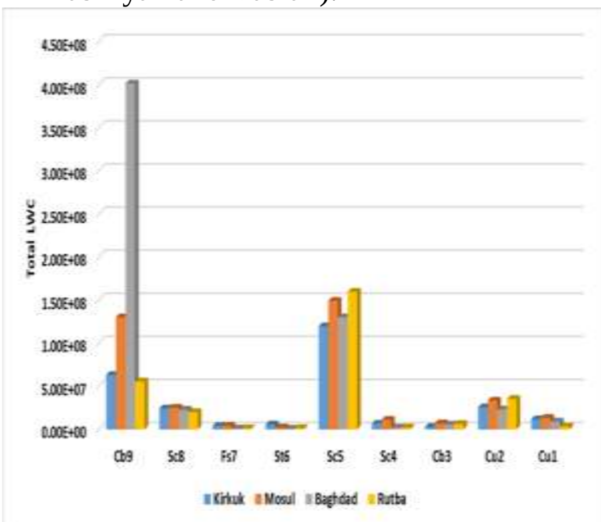

Figure 6. shows the attributing of each cloud at four indicated stations

The Cb9 and Sc5 have values [74504664 m^3] and [72053280 m^3] at Al-Nasiriya station. At third rank, the Cu2 value is [217978800 m^3], at fourth rank the Sc8 value is [124647600 m^3] of liquid water, and at fifth rank, the Cu1 value is [67239900 m^3] liquid water. Figure (7) illustrates, the variance of total amount of liquid water, which is [594882168 m^3] and [512583240 m^3] in Baghdad and Basrah stations respectively. This gives sufficient idea about the changing in amount of water supplies among the cloud's types.

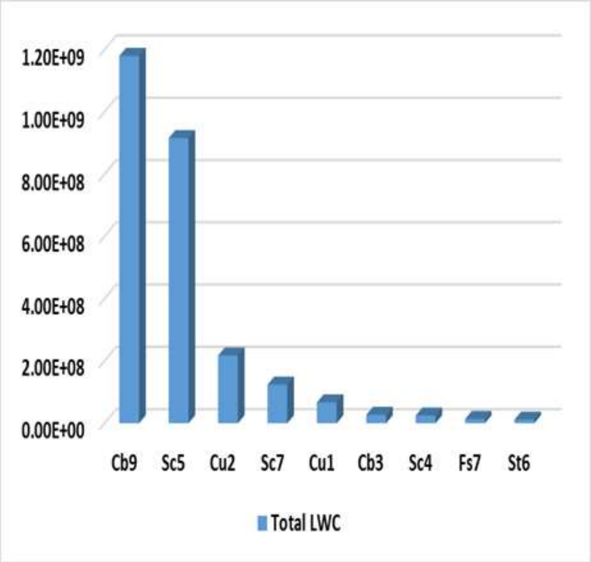

Figure 7. Shows comparing total attribute sharing of each cloud

Analyzing of main supplies cloud type at the stations:

First: Analyzing the attributing at station form each cloud

-It has turned out the Cb9 type supplies the greatest amount at study stations, but must indicate its tendency at the studied stations. It is clear the (Cb9) takes the first place at both Baghdad and Basrah.

-Nevertheless, the Cb9 type comes at the second place over Al-Mosul and Al-Nasiriya.

-When discuss the (Sc5) type, clearly it takes the first place at (Al-Mosul, Al-Rutba and Al-Diwaniyah)

-And both Cu2 and Sc8 are competing at the third rank at Al-Mosul, Kirkuk, Al-Rutba, Al-Hai, Al-Nasiriyah, Basrah.

Second: Analyzing the total attribute of all clouds:

-It clears from figure 3 the Cb9 comes at first rank in supplying liquid water, the Sc5 comes at second, and the Cb3 and Sc8 comes at the third and fourth rank respectively.

Classifying the low-level cloud water supply at studied stations.

Table 5. classifying of studied cloud through 1975 to 2005

stations	First Rank	Second Rank	Third Rank	Fourth Rank
Al-Mosel	Sc5	Cb9	Cu2	Sc8
Kirkuk	Sc5	Cb9	Cu2	Sc8
Baghdad	Cb9	Sc5	Cu2	Sc8
Al-Rutba	Cb9	Sc5	Cu2	Sc8
Al-Hai	Cb9	Sc5	Cu2	Sc8
Diwaniyah	Cb9	Sc5	Cu2	Sc8
Al- Nasiriya	Cb9	Sc5	Cu2	Sc8
Basra	Cb9	Sc5	Cu2	Sc8

CONCLUSIONS

1- The (Cb9, Sc5) gives the greatest amount of liquid water, and somewhat (Sc8, Cu2,) in the second rank at each one of (Al-Mosul, Kirkuk, Baghdad, and Al-Rutba) stations. (Cb9) type can supplies about [129905568 m^3] and about [401178960 m^3] of liquid water per year at Al-Mosul and Baghdad stations. The other types of clouds are too least. It must be giving a serious attention to observing (Sc5, Cb9, Sc8 and Cu2) type to get the greatest benefit

2- The effect of the low-level clouds shows, that the two types cloud (Cb9, Sc5) taking the first rank at supplying liquid water at each of (Al-Hai, Diwaniyah, Al- Nasiriya and Basra).

3- (Cb9) type supplies the greatest amount at study stations, And It's takes the first place at both of (Baghdad and Basra). But it comes at the second place at (Al-Mosul and AL-Nasiriya).

4- The average annual total frequency of all types of Low clouds for the period thirty years start from (1975) end to (2005), are [4532 cloud per year] at all Iraq. Stratocumulus clouds [Sc5] the most repeat over Iraq is 1489 times per year, so the percentage of a repeat of this type of clouds is [32.85%]. The broken cumulus stratified stratocumulus [Sc8] annual repetition rate of [836] times per year, so the percentage of a repeat of this type of clouds is [18.42%]. while cumulus convective cloud (Cu1) rate of repeat annual is [821] times per year, the Percentage of recurrence of this kind of clouds is [19.28%].

5- The clouds type (Sc5) takes the first place at (Al-Mosul, Kirkuk, Al-Rutba, Al-Hai, Diwaniyah and AL-Nasiriya). Both of (Cu2&sc8) are competing at the second rank at all of studied stations.

6- At this case, can get benefit from the main four low – level clouds (Cb9, Sc5, Cu2, and Sc8) in supplying liquid water, for cloud seeding process.

7- This study, found when examine clouds in terms of frequency, the cloud (Sc5) type has more repeated [194] times, at Kirkuk station, takes first rank with percentage of [27.4 %], While, when examining the types of clouds, depending on the maximal amount of its water content, cloud type (Cb9) takes first rank with about [1180612368 m3].

8. An important conclusion is that the success to investing of the cloud seeding process should focus on the two types of clouds (Cb9 and Sc5) and give attention to its appearance.

9- Depending on the average annual of the period for all types of Low clouds for the thirty years from 1975 end to 2005[4653 cloud per year], rain improvement rates can be obtained by experience Cloud Seeding, with success rates Enhancement of Rain from 5% to 20% of clouds class (St) و rates cumulus clouds (Cu) up to 100%, and guaranteed success of Cumulonimbus clouds thunderstorms (Cb9).

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