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A study of kinematic vertical motions in the troposphere in Iraq

Hassan H.Salman, Sama K. AL-Dabbagh, Hadil J. AL-Shouhani

Department of Atmospheric Sciences, College of Science, AL-Mustansiriyah University, Baghdad, Iraq.

Abstract
Vertical velocity has been computed kinematically, and divergence has been calculated by finite differences method by using Taylor theory at levels (1000 to 250) HPa for the first day of January and July, 2010. The data used in this study covered Iraq as a grid of twelve points extends from (30°-36°) N latitudes and (40°5'- 46°5') E longitudes with a uniform grid interval of 3 degrees longitude and 3 degrees latitude. O'Brien adjustment technique has been used to correct the computed divergence and vertical velocity. This study showed that, after comparing the results with the synoptic features, in general there is compatibility between the corrected vertical velocity and the synoptic features.

Keywords: Divergence; Iraq; Kinematic method; Vertical motion; Vertical velocity.

1. Introduction

The vertical wind velocity is not an observed variable in meteorology. And its estimation appears as one of the most difficult problems [1].
The calculation of the vertical velocity is very important due to its impact on the daily weather. It has an explanatory role in the formation of clouds and dust were carrying water vapor upward so it condenses. And as a result of self-cooling transforms, the droplets form the clouds and rain, depending on the amount of humidity. Besides, it considered as the main cause for the dust if there was other factors such as the disintegration of dry soil and poor vegetation. It does not work on lifting the dust only, but also by controlling the period of its survival in the atmosphere [2].
An unfortunate consequence of their small magnitudes is that these vertical motions cannot be directly measured, but rather must be calculated using other measured variables [3].
The methods commonly used have been called (1) kinematic method, (2) adiabatic method, (3) trajectory method and (4) numerical method. Each method has certain inherent advantages and disadvantages.
The kinematic method uses the continuity equation in pressure coordinates to obtain the vertical motion from the horizontal divergence. The primary advantage of this method lies in its mathematical simplicity and in the fact that hydrostatic balance is the only assumption. However, errors in the wind observation as well as in the computed horizontal divergence often tend to accumulate through the vertical integration. As a result unrealistic estimates of vertical velocities are often found in the upper troposphere [4].
Some techniques have been discussed in previous studies (e.g. Lateef 1963, Fankhauser 1969, O'Brien 1970, Smith 1971) to reduce the cumulative errors. The study by Lateef indicated that the vertical velocity patterns obtained from the modified kinematic method appear realistic though the absolute

magnitudes maybe in error [5]. Fankhauser 'study suggested that the kinematic method has a sufficient reliability if some techniques are employed [6]. O'Brien has discussed the theoretical bases of many adjustment techniques [7]. Smith examined two of these techniques and found that the kinematic ώ are realistic as far as the observed weather is concerned [8]. And a case study by Chen showed that Radar reports indicated that the computed kinematic ώ are in reasonably good agreement with the cloud echoes [4].

This study aims to calculate vertical velocity by the kinematic method using the equation of continuity, which represents a mathematical formula for the law of conservation of mass using the horizontal wind data (u, v) and calculate the divergence using finite differences method by using Taylor theory, and to adjust the calculated values of both divergence and vertical velocity by using O'Brien adjustment technique.

2. Theory

2.1 The calculation of the divergence and the vertical velocity

The equation of continuity in pressure coordinates is [9]

$$\frac{\partial \omega}{\partial p}+\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

where ω is the change in the vertical velocity with respect to pressure($\mu Pa.sec^{-1}$),u and v are the horizontal velocity components($m.sec^{-1}$), are measured relative to a constant pressure surface P.

This equation can be used to compute the vertical velocity at various levels in the atmosphere. This technique is called the kinematic method because it only requires information about the winds.

To estimate the horizontal divergence represented by the term $\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)$, consider there is a grid composed of four points (A,B,C,D) where the horizontal wind data (u,v) are available for each point at a given pressure level as shown in Figure 1. And in the center there is point (E) which we intend to calculate the vertical velocity using the finite differences method. Notice that this method assumes the wind field varies linearly between grid points.

When a function u and its derivatives are single-valued, finite, and continuous functions of x, then by Taylor's theorem [10]

$$u(x+h)=u(x)+hu'(x)+\frac{1}{2}h^2u''(x)+\frac{1}{6}h^3u'''(x)+.... \tag{2}$$

$$u(x-h)=u(x)-hu'(x)+\frac{1}{2}h^2u''(x)-\frac{1}{6}h^3u'''(x)+.... \tag{3}$$

Addition of these expansions and neglect the terms containing fourth and higher power gives:

$$u'(x)=(\frac{\partial u}{\partial x})\approx\frac{1}{2h}\{u(x+h)-u(x-h)\} \tag{4}$$

The same way can be used to estimate:

$$v'(y)=(\frac{\partial v}{\partial y})\approx\frac{1}{2h}\{v(y+h)-u(y-h)\} \tag{5}$$

h here means ∂x or ∂y which they represent the longitudes and the latitudes in degrees.

By adding (4) & (5) we will estimate the horizontal divergence for a given pressure level P.

After rearrange (1) and Integrate from p1 to p2 we get [7]:

$$\omega_{p_2} = \omega_{p_1} - \int_{p_1}^{p_2} (\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y})dp \tag{6}$$

If the horizontal divergence is constant for the layer between p1 and p2, we can represent this equation in finite difference form:

$$\omega_{p_2} = \omega_{p_1} + (\left[\overline{\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}}\right])(p_1 - p_2) \tag{7}$$

where ω_{p_2} the vertical velocity at p2 is, ω_{p1} is the vertical velocity at p1, $\overline{\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}}$ is the averaged horizontal divergence for the layer between two pressure levels (p1 and p2).

If $D_k = (\left[\overline{\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}}\right])(p_1 - p_2)$ equation (7) becomes:

$$\omega_k = \omega_{k-1} + D_K \tag{8}$$

The above equation was used to calculate the vertical velocity at a pressure level P.
However, it is well known that ω_k become successively less acceptable as k increase, due to errors in the estimation of D_K. The value of ω at the top of any column usually is found to be either too low or too high when compared with independent, physically realistic estimates [7].
O'Brien proposed adjustments techniques which have been applied to kinematic vertical motions and horizontal divergence as it will show in the next item.

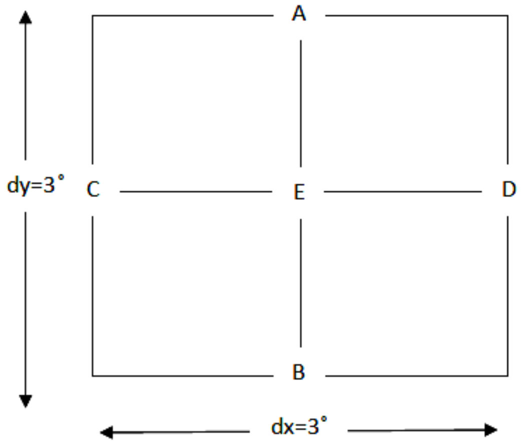

Figure 1. Grid used for finite differences

2.2 The adjustment of the divergence and the vertical velocity
O'Brien [7] proposed a technique which it used by many researchers to estimate the adjusted divergence D_K' and ώ which represents the adjusted vertical velocity by using the bellow equations:

$$D_k' = D_k - \frac{k}{M}(\omega_K - \omega_T) \tag{9}$$

$$M = \sum_{k=1}^{K} k = \frac{1}{2} K(K+1) \tag{10}$$

where k the integer value for the individual level, K the integer value for the top level, D_k, ω_k, ω_K the unadjusted computed value at k, K, ω_T the assumed correct value at the top of the column.

3. Materials and methods

3.1 Data

The data used in this study covered Iraq as a grid of twelve points extends from (30°-36°) N latitudes and (40°5'- 46°5') E longitudes with a uniform grid interval of 3 degrees longitude and 3 degrees latitude for the first day of January (winter) and for the first day of July (summer) and for the time (00 and 12) UTC.

The input data consists of the horizontal wind velocity (u, v) and relative humidity at six levels (1000,850,700,550,400,250) HPa from the ECMWF (European Centre For Medium-Range Weather Forecasts) and cloud cover and total precipitation from the same centre. It should be noted that The ECMWF values are not really observed, of course, but from a numerical model.

first the divergence were calculated for each level kinematically using finite differences method for four points which located in the four regions: Anah, Khanaqin, Nukhaib and Samawa which have different topography depending on their location. And second the vertical velocity was calculated for the same four points as shown in Figure 2.

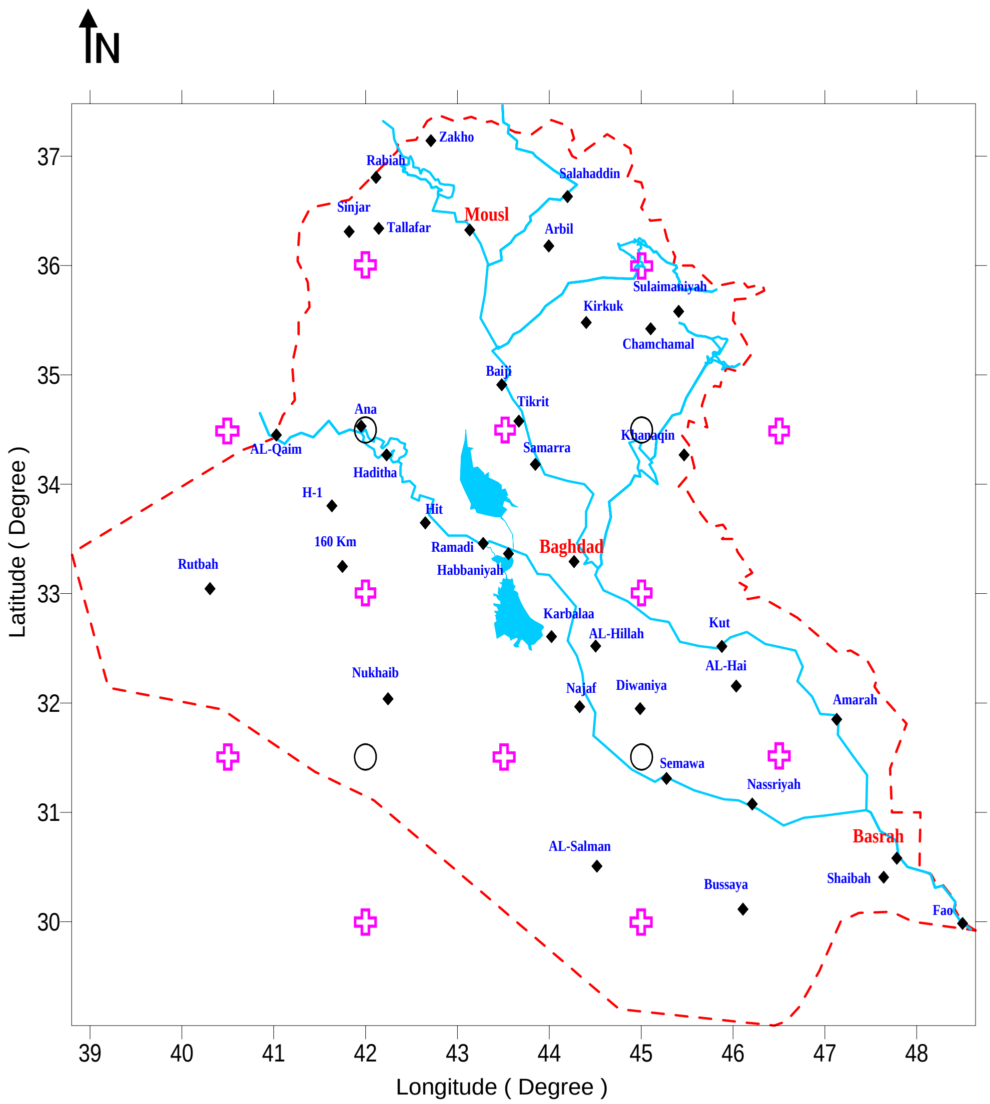

Figure 2.Grid data points (cross shape) and the calculated points (circle shape)

3.2 Some notes about the calculation of divergence

To find the value of h in equation (4) & (5) which represents the distance between the longitudes and the latitudes for each two points ($\partial x, \partial y$), we should estimates the actual distance on earth.

But the distance between the all points of chosen grid must be the same in longitudes and latitudes as required by the way of finite differences method. Degrees of latitude are parallel so the distance between each degree remains almost constant but since degrees of longitude are farthest apart at the equator and converge at the poles, their distance varies greatly [11]. Therefore we used the "haversine" formula to find the distance between two longitudes for constant latitude and found the average which equals to 139.6 kilometer per 1.5° (i.e. the distance equals to 93.067 kilometer per 1°as it shown in Table 1, on the basis of a spherical earth (ignoring ellipsoidal effects) which is accurate enough for most purposes. Using a spherical model gives errors typically up to 0.3 % [12].

3.3 Some notes about the calculation and adjustment of the vertical velocity

For the issue of calculating the vertical velocity, if one assumes that the horizontal wind velocity at the surface is zero then the horizontal divergence becomes zero, and the vertical velocity equals to zero at the lower boundary (i.e. $\omega_0 = 0$).

Results obtained from equation (8) were physically realistic and acceptable in low and middle tropospheric levels but diminished in credibility in the upper layers. That's why it is necessary to use O'Brien technique for adjust the value of D_k & ω_k .

Table 1. The real estimates distance between longitudes in kilometer

Latitude	Longitude							
	37°5'-39°	39°-40°5'	40°5'-42°	42°-43°5'	43°5'-45°	45°-46°5'	46°5'-48°	48°-49°5'
39°	129.6	129.6	129.6	129.6	129.6	129.6	129.6	129.6
37°5'	132.3	132.3	132.3	132.3	132.3	132.3	132.3	132.3
36°	134.9	134.9	134.9	134.9	134.9	134.9	134.9	134.9
34°5'	137.5	137.5	137.5	137.5	137.5	137.5	137.5	137.5
33°	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9
31°5'	142.2	142.2	142.2	142.2	142.2	142.2	142.2	142.2
30°	144.4	144.4	144.4	144.4	144.4	144.4	144.4	144.4
28°5'	146.6	146.6	146.6	146.6	146.6	146.6	146.6	146.6
27°	148.6	148.6	148.6	148.6	148.6	148.6	148.6	148.6
Average distance [Km]	139.56	139.56	139.56	139.56	139.56	139.56	139.56	139.56

4. Results and discussions

As mentioned before, the vertical velocity have been estimated at various levels using kinematic method, and the correction which described by O'Brien were applied to both calculated divergence and vertical velocity. Synoptic features were compared with the results to show the compatibility between them. And they include the relative humidity for pressure levels for the first day of January and July 2010 at 00 am and 12 pm for different grid points as shown in Table 2, and the total cloud cover and the total precipitation for the same date and time as shown in Table 3. All the data has been taken from the ECMWF, and sea level pressure maps for the same date and time as shown in Figure 3 has been taken from National oceanic and atmospheric administration (NOAA).

By matching the results with the synoptic features at the selected time for the selected points, generally, the maximum adjustment for the divergence and the vertical velocity were at the upper atmospheric layers, while, near the boundary layer the correction equals to zero.

From the results, in July (as one of the summer months) the vertical motion were positive (downward).and this situation was more obvious at night and this means the weather was stable, while in January (as one of the months of winter) the vertical motion between upward and downward and this is

due to the prevailing weather at that time and the nature of the region (as will be clarified later). Therefore, the values of the vertical velocity in summer is higher than winter.
It was noticed also from the results in general that the relationship between the signs of horizontal divergence and the vertical velocity were not very compatible, especially in the upper layers.
After matching the synoptic features with the results from this study, it was noticed that there is compatibility between the synoptic features and the corrected vertical velocity as it discussed below.

Table 2. The relative humidity for pressure levels for the first day of January and July 2010 at 00 am and 12 pm for different grid points

R.H. for the point located in Anah				
Pressure	January		July	
HPa	00:00	12:00	00:00	12:00
1000	90	54	19	10
850	57	17	17	20
700	9	22	27	18
550	21	37	2	3
400	27	27	1	1
250	11	82	14	11

R.H. for the point located in Khanaqin				
Pressure	January		July	
HPa	00:00	12:00	00:00	12:00
1000	99	73	21	8
850	100	82	19	13
700	91	26	10	9
550	14	32	2	-1
400	27	36	2	1
250	7	26	22	15

R.H. for the point in Nukhayb				
Pressure	January		July	
HPa	00:00	12:00	00:00	12:00
1000	83	17	21	9
850	84	67	20	17
700	17	17	35	37
550	15	17	1	4
400	18	19	2	2
250	24	56	28	12

R.H. for the point in Samawah				
Pressure	January		July	
HPa	00:00	12:00	00:00	12:00
1000	76	50	18	11
850	82	65	18	19
700	36	18	28	19
550	15	20	3	1
400	28	19	2	1
250	7	39	10	10

Table 3. The total cloud cover and total precipitation for the first day of January and July 2010 at 00 am and 12 pm for different grid points

At the point located in Anah				
Cloud type	January		July	
	00:00	12:00	00:00	12:00
High cloud	0	0	0	0
Middle cloud	0	0	0	0
Low cloud	0	0	0	0
Total precipitation	0	0	0	0

At the point located in Khanaqin				
Cloud type	January		July	
	00:00	12:00	00:00	12:00
High cloud	0	0	0	0
Middle cloud	0.4	0	0	0
Low cloud	1	0.6	0	0
Total precipitation	0	0.98	0	0

At the point located in Nukhayb				
Cloud type	January		July	
	00:00	12:00	00:00	12:00
High cloud	0	0	0	0
Middle cloud	0	0	0	0
Low cloud	0	0	0	0
Total precipitation	0	0	0	0

At the point located in Samawah				
Cloud type	January		July	
	00:00	12:00	00:00	12:00
High cloud	0	0	0	0
Middle cloud	0.1	0	0	0
Low cloud	0.1	0	0	0
Total precipitation	0	0	0	0

*The units of the cloud cover (0-1), total precipitation in mm.

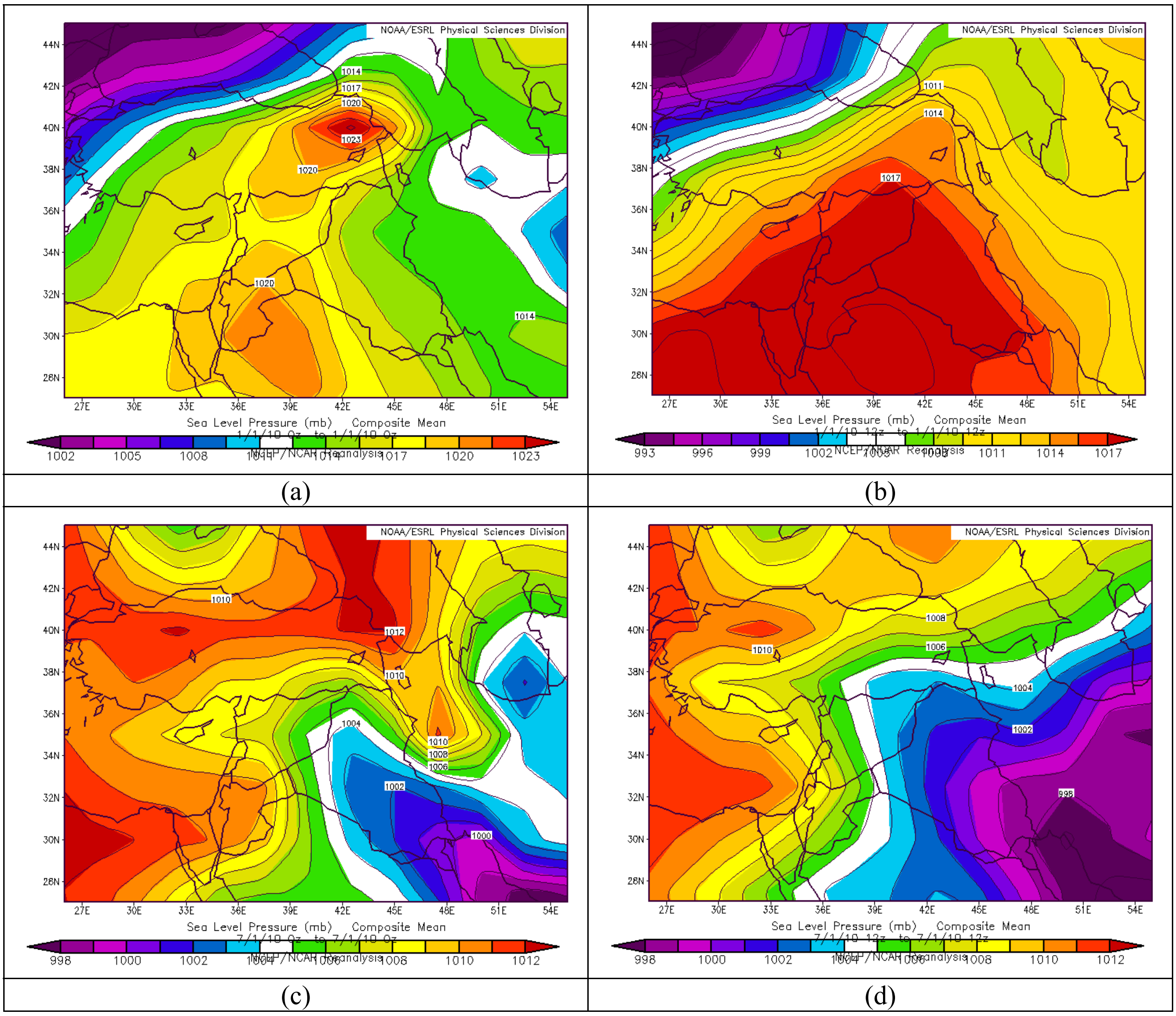

Figure 3. Sea level pressure map: A & B for the first of January 2010 at 00 am and 12 pm, C & D for the first of July 2010 at 00 am and 12 pm

Figure 4 which represents the calculated divergence and the vertical velocity with their correction for a point located at (34°5'N, 42°E) in the town of Anah which lies to the west of Iraq, results at 00 am (at night) in January Figure 4A, shows that the vertical motion was upward and the weather was clear although the high relative humidity. This was due to its position in the region of the low pressure declination where the value of the pressure at the center of the low pressure was 1014 HPa(Figure 3A). The maximum value of the vertical velocity was -0.35µPas/sec at 250 HPa. While in the day time at 12 pm Figure 4B, the same region has been influenced by high pressure (Figure 3B) and the weather was clear although the high relative humidity but the results show that the vertical motion was upward, perhaps this is due to the existence of some local effects (secondary low pressure may formed). The maximum value of the vertical velocity was -0.13µPas/sec at 850 HPa.

Figure 4C represent the same region in July at 00 am, the vertical motion were upward at 850HPa and downward in the upper layers. But the weather was clear due to the low relative humidity and of the influence of the monsoon on the region (Figure 3C).The maximum value of the vertical velocity were 5.01µPas/sec at 400 HPa. While in day time at 12 am the same region was under the effect of the extended high pressure (Figure 3D), that's why the vertical motion was downward as shown in Figure 4D. Add to that the low relative humidity so the weather was clear. The maximum value of the vertical velocity was 1.44µPas/sec at 400 HPa.

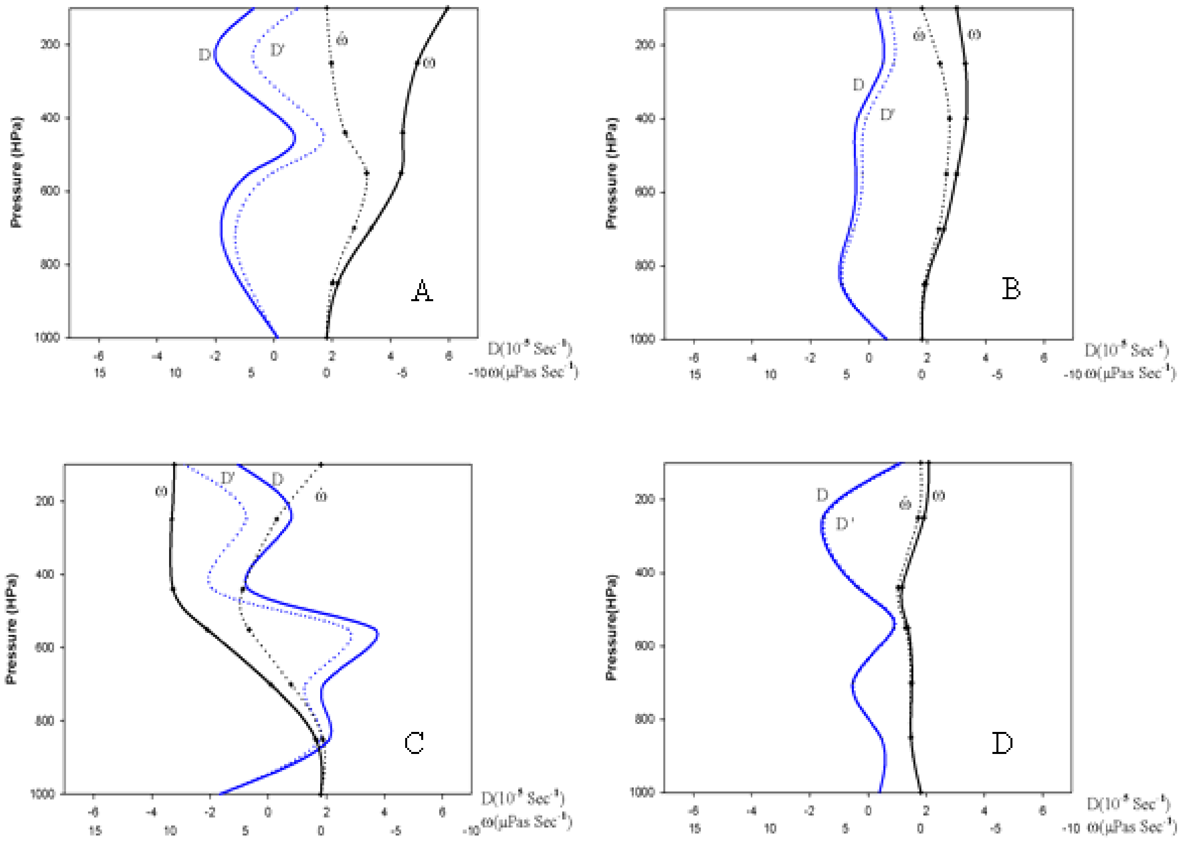

Figure 4. Vertical profiles of unadjusted (solid)D&ω and the adjusted (dashed) D'&ώ for the point located in Anah. A & B is for the 1st of January 2010 at 00 am and 12 pm, C & D is for the 1st of July 2010 at 00 am and 12 pm

Figure 5 which represents the same calculated variables in Figure 4 for a point located at (34°5'N, 45°) in the city of Khanaqin which lies to the east of Iraq, and it considered as semi mountainous. Results at 00 am (at night) in January. Figure 5A show that the vertical motion was upward and the synoptic features appeared that the area lies under the influence of low pressure (Figure 3A). Due to the high relative humidity and the previous effects, the low cloud cover was full and the middle cloud cover was 0.4 according to the ECMWF as shown in table 3.

The maximum value of the vertical velocity was -0.73µPas/sec at 850 HPa. While in day time at 12 am, the vertical motion was downward at the upper layers and as shown in Figure 5B and high pressure prevailed the region (Figure 3B). This is caused a cloudy weather with light rain about 0.98 mm (Table 3). The maximum value of the vertical velocity was 2.33µPas/sec at 400 HPa.

In July as shown in Figures 5C and 5D for both 00 and 12 UTC, the point lies between two different regions of high pressure and low pressure (Figure 3C and 3D). The results show that the vertical motion was downward, and because of the low relative humidity, the weather was clear. The maximum value of the vertical velocity at 00 UTC was 1.35µPas/sec at 700 HPa, while the maximum value of the vertical velocity at 12 UTC was 4.94µPas/sec at 400 HPa

Figure 6 represents the same calculated variables for the point located at (31°5' N), (42°E) which lies near the city of Nukhayb. In January, the region was under the influence of high pressure (Figure 3A), and the results show that the vertical motion was downward as shown in Figures 6A and 6B. That's why the weather was clear. The maximum value of the vertical velocity at 00 UTC was 5.05µPas/sec at 400 HPa, and at 12 UTC, it was 2.54µPas/sec at 400 HPa

In July, the monsoon effects on the same region (Figures 3C and 3D). It was noticed from Figure 6C that at night the vertical motion was upward at 850 HPa and downward in the upper layers. So that the weather was clear. The maximum value of the vertical velocity at 00 UTC was 1.27µPas/sec at 400 HPa

While in day time the upward vertical motion extended to the upper air as shown in Figure 6D because of the increment of air ascension, and the weather was clear. The maximum value of the vertical velocity at 12 UTC was -0.38092µPas/sec at 250 HPa.

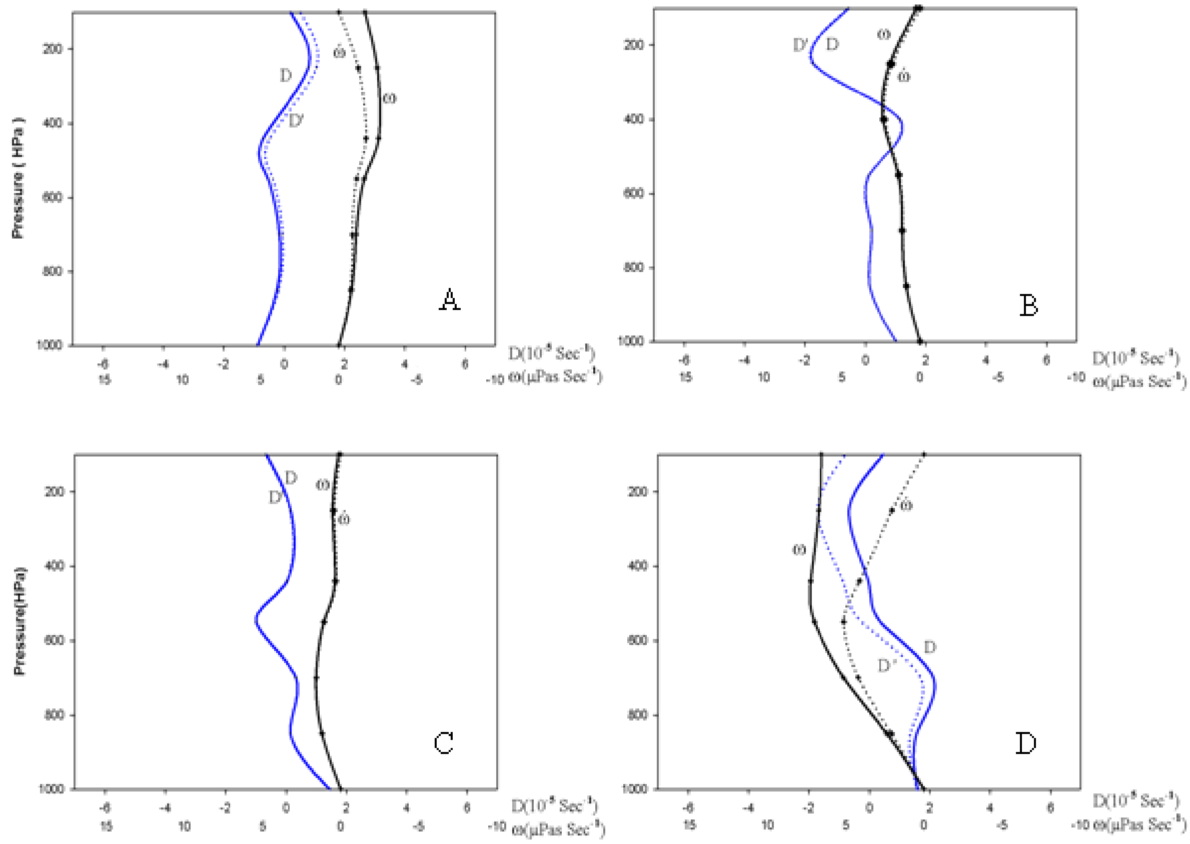

Figure 5. Vertical profiles of unadjusted (solid)D&ω and the adjusted (dashed) D'&ώ for the point located in Khanaqin. A & B is for the 1st of January 2010 at 00 am and 12 pm, C & D is for the 1st of July 2010 at 00 am and 12 pm

Figure 7 represents the same calculated variables for the point located at (31°5' N), (45°E) which lies in the city of Samawah in the south of Iraq. In January, the region was under the influence of high pressure (Figures 3A and 3B). The results in Figures 7A and 7B shows that the vertical motion at 00am was downward, accompanied by few middle and low clouds (Table 3). The maximum value of the vertical velocity was 0.82µPas/sec at 700HPa.while in day time at 12 pm the weather was clear. The maximum value of the vertical velocity was 1.86 µPas/sec at 400 HPa.

As for July, the region was located between two regions of high and low pressure (Figures 3C and 3D), and the results shows that the vertical motion was downward as shown in Figures 7C and 7D. Add to that the low relative humidity so the weather was clear. The maximum value of the vertical velocity at 00 am was 7.77µPas/sec at 400 HPa. While at 12 pm the maximum value was 8.96 µPas/sec at 550 HPa.

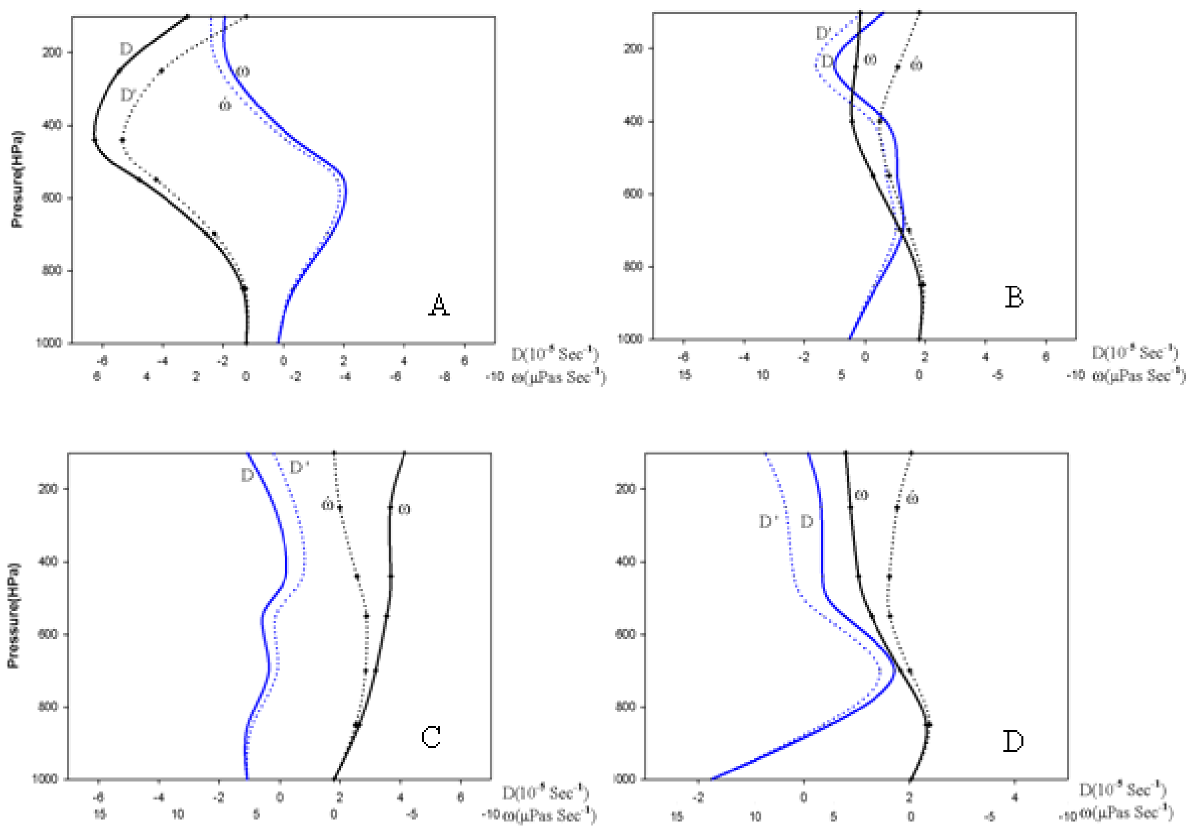

Figure 6. Vertical profiles of unadjusted (solid) D&ω and the adjusted (dashed) D'&ώ for the point located near Nukhayb. A & B is for the 1st of January 2010 at 00 am and 12 pm, C & D is for the 1st of July 2010 at 00 am and 12 pm

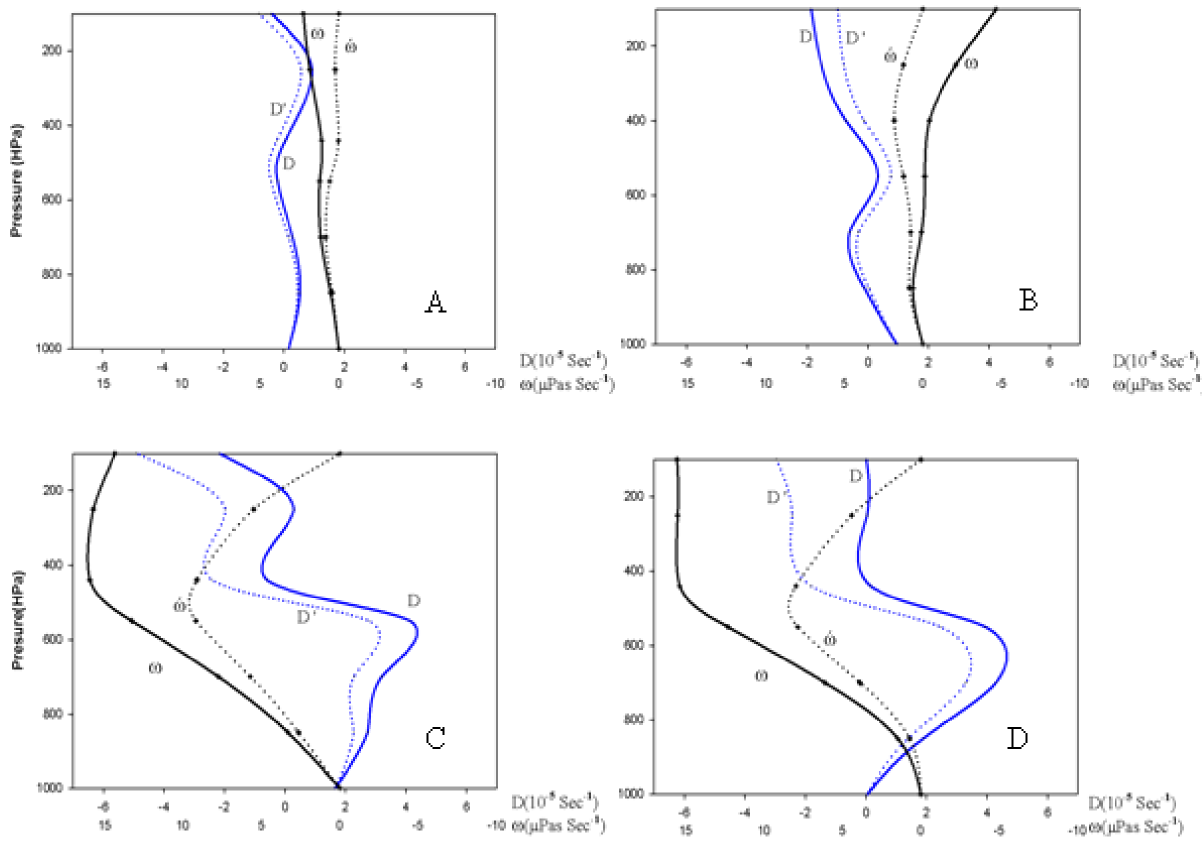

Figure 7. Vertical profiles of unadjusted (solid) D&ω and the adjusted (dashed) D'&ώ for the point located in Samawah. A & b is for the 1st of January 2010 at 00 am and 12 pm C & d is for the 1st of July 2010 at 00 am and 12 pm

5. Conclusion

After being illustrate the results, they can be summarized as follows:

In general, there is compatibility between the synoptic features and the corrected vertical velocity. In areas that were dominated by the high pressure, especially in winter, the weather was clear, and vertical motion was downward. The results showed also clear sky in summer in the region lies between high and low pressure, with downward vertical motion. And due to the effect of Indian Monsoon Low on Iraq in summer, some results showed there was a clear sky and upward vertical motion, while in areas that were dominated by low pressure in winter, the vertical motion was upward and the weather was cloudy.

Results showed also in three cases, if there is divergence in the upper tropospheric flow pattern, it can cause ascending motion in the air column, and the surface pressure decrease and this lead to cloudy weather. Contrary, convergence in the upper tropospheric flow pattern can cause descending motion in the air column, and the surface pressure increase and this lead to clear weather.

The maximum adjustment for the divergence and the vertical velocity where at the upper atmospheric layers, while, near the boundary layer the correction equals to zero. In some points, the correction was zero in the lower and upper layers.

In July the vertical motion were positive (downward).and this was more obvious at night which lead to a stable weather, while at January, the vertical motion was ranging between upward and downward and this is due to the prevailing weather at that time and the nature of the region. Therefore, the values of the vertical velocity in summer is higher than winter. And, the relationship between the signs of horizontal divergence and the vertical velocity were not very compatible, especially in the upper layers.

References

[1] Krishnamurti T.N., Bounoua L.An introduction to numerical weather prediction techniques. CRC Press, United State of America, 1996.

[2] Al-Jibouri M.K Study of vertical wind motion and some of its meteorological effects in Iraq. M.A.Sc. Thesis, University of Al-Mustansiryah, 1994.

[3] Smith G.D. Numerical solution of partial differential equation. Oxford University Press, 1971.

[4] Chen G.T.J. A composite case study of kinematic vertical motion. Atmos. Sci., Meteor. Soc. Rep. of China. 1976, 3, 87-105.

[5] Lateef M.A. Vertical motion, divergence, and vorticity in the troposphere over the Caribbean, Aug.3-5, 1963. 1967, 95, 788-790.

[6] Fankhauser J.C. Convective processes resolved by a meso-scale rawinsonde network, journal of applied meteorology, 8(5), p.778-798, 1969.

[7] J.J.O'Brien – Alternative solutions to the classical vertical velocity problem– J. Applied Meteorology, 1970, 9(2), 197-203.

[8] Smith P.J.An analysis of kinematic vertical motions, monthly weather review, 1971, 99(10), 715-724.

[9] Pond S., Pickard G.L. Introductory dynamical oceanography, Pergamon Press, Great Britain, Second Edition, 1983.

[10] Smith G.D. Numerical Solution of Partial Differential Equation, Oxford University Press, 1971.

[11] Furstinger, N.White, N., Korb, R.B.,Weinberg, F., Miller, R.A. Get ready!for social studies: Geography, McGraw-Hill Professional, United State of America,2002.

[12] Sambells J., Purvis M., Lewis A.,Turner C. Beginning Google maps applications with Rails and Ajax, A press, United State of America, 2007.

Hassan H. Salman is Ph.D. in Geological Sciences (with specialization in Hydrology and hydrometeorology) from University of Baghdad, Iraq in 1987. He has completed M.Sc. and B.Sc in Geology from Baghdad University, Iraq in 1977 and 1974, respectively. He has been teaching and conducting research in Atmospheric Sciences and related fields in the College of Science, Al-Mustansiriyah University since 1996. Before that and since 1977, he was a research scientist in Marine Science Center, Basrah University, Iraq. He has published more than 50 research papers in refereed International and National journals/conferences, Dr. Salman supervised more than 20 Ph.D. theses. He is currently working as a Professor in the Department of Sciences, Al-Mustansiriyah University, Iraq.
E-mail address: salmanmet@hotmail.com

Sama. K. Al-Dabbagh is M.Sc. in Atmospheric Sciences (with specialization in Cloud Physics) from Al-Mustansiriyah University, Iraq in 2000. and B.Sc. in Atmospheric Sciences from Al-Mustansiriyah University, Iraq in 1997.She has been teaching and conducting research in Atmospheric Sciences and related fields in the College of Science, Al-Mustansiriyah University since 2006. She has published one research paper, Miss Sama is currently working as an assistant lecturer in the Department of Sciences, Al-Mustansiriyah University, Iraq.
E-mail address: samaaldabag1@yahoo.com

Hadil J. Al-Shouhani is M.Sc. in Atmospheric Sciences (with specialization in Ionosphere) from Al-Mustansiriyah University, Iraq in 2000. and B.Sc. in Physics from Al-Mustansiriyah University, Iraq in 1996. She has been teaching and conducting research in Atmospheric Sciences and related fields in the College of Science, Al-Mustansiriyah University since 2006. Mrs.Hadil is currently working as an assistant lecturer in the Department of Sciences, Al-Mustansiriyah University, Iraq.
E-mail address: hadeel.jaleel@yahoo.com