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Distribution of Atmospheric Stability Classes in Baghdad Province and Its Relationship with Surface Wind Speed Rates

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Abstract

Stability in the atmosphere is the most important factor in the transport and dispersion of air pollutants. There are a number of complicated methods for determining stability. The majority of these methods are based on the amount of convective and mechanical turbulence in atmospheric motions, such as the Richardson number, Monin-Obukhov length, Pasquill-Gifford stability classification, and Pasquill-Turner stability classification. Pasquill utilized surface-accessible meteorological information like breeze speed, sun-based radiation, and surface darkness to portray air steadiness. Baghdad territory was separated into a gathering of focuses as indicated by scope and longitude; six focuses were chosen and conveyed in a manner that addresses all districts of Baghdad territory through the diurnal hourly information (6, 9, 12, 15, 18) for the months (January, April, July, October) for the year 2018, and find the spatial and fleeting circulation of relative recurrence RF% dependability classes as per consolidating the Pasquill-Turner strategy. The pattern of conditions necessary for atmospheric stability can be derived from two distinct categories. First, the patterns for the month and the season are calculated. The results show that in April, the relative frequency (RF%) of the (A) and (B) classes is highest in the northeast of Baghdad province and has an inverse relationship with average wind speed (R = - 0.62, - 0.90). During July, the relative frequency RF percentages of the (C) and (D) classes are highest in the west and northeast of Baghdad province, respectively, and they are positively correlated with average wind speed (R = 0.91, 0.78, respectively). The spatial and worldly conveyance of relative recurrence RF% steadiness classes as per joining the Pasquill-Turner strategy prompts a feeble relationship or an absence of clarity in the relationship because of the impact of affecting elements (non-direct variety) (the Pasquill-Turner Technique (PTM) in extra factors of the Pasquill strategy). Second, monthly and seasonal patterns are calculated. The Pasquill method reveals that the stability class (C) has the highest relative frequency (RF%) in January (28.72 percent), the stability class (B) has the highest relative frequency (RF%) in April (33.98 percent), the stability class (C) has the highest relative frequency (RF%) in July (64.74 percent), and the stability class (C) has the highest relative frequency (RF%) in October (35.48 percent).

Keyword: atmospheric stability, classes, frequency, wind speed, Baghdad

توزيع اصناف الاستقرارية الجوية في محافظة بغداد وعلاقتها بمعدلات سرعة الرياح السطحية

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الخلاصة

الاستقرارية في الغلاف الجوي هو العامل الأكثر أهمية في نقل وانتشار ملوثات الهواء. هناك عدد من الطرق المعقدة لتحديد الاستقرارية. تعتمد غالبية هذه الطرق على مقدار الاضطراب الحملي والميكانيكي في حركات الغلاف الجوي، مثل رقم ريتشاردسون، وطول مونين-أوبوكوف، وتصنيف باسكيل-جيفورد للاستقرار، وتصنيف باسكيل-تيرنر للاستقرار. استخدم باسكويل معلومات الأرصاد الجوية التي يمكن الوصول إليها على السطح مثل سرعة الرياح والإشعاع الشمسي والغيوم لتوصيف استقرار الغلاف الجوي. تم تقسيم محافظة بغداد إلى مجموعة من النقاط حسب خطوط الطول والعرض ؛ تم اختيار ستة نقاط موزعة بطريقة تمثل جميع مناطق محافظة بغداد من خلال البيانات النهارية اليومية للساعات (6، 9، 12، 15، 18) للاشهر (كانون الثاني، نيسان، تموز، تشرين الاول) لعام 2018، و والتوزيع المكاني والزماني للتكرار النسبي لاصناف الاستقرارية RF٪ طبقًا للجمع بين طريقة Pasquill –Turner. يمكن استخلاص نمط الظروف اللازمة لاستقرار الغلاف الجوي من فئتين متميزتين. أولاً، تم اشتقاق الأنماط الشهرية والموسمية. بينت النتائج ان شهر نيسان كان التكرار النسبي (RF%) للصنفين (A) و (B) هو الاعلى في شمال شرق بغداد وله علاقة عكسية مع متوسط سرعة الرياح (R = − 0.62, − 0.90). خلال شهر تموز، كانت نسب التكرار النسبي (RF%) للصنفين (C) و (D) هي الأعلى في غرب وشمال شرق محافظة بغداد، على التوالي، وترتبط بشكل إيجابي مع متوسط سرعة الرياح (R= 0.91,0.78) على التوالي. يؤدي التوزيع المكاني والزماني لنسبة التكرار النسبي لاصناف الاستقرارية (RF %) وفقًا للجمع بين طريقة باسكويل-تيرنر Pasquill–Turner إلى علاقة ضعيفة أو غياب الوضوح في العلاقة بسبب تأثير المعاملات المؤثرة (غير الخطية المتعددة) (طريقة Pasquill–Turner PTM) (بالاضافة الى العوامل الخاصة بطريقة باسكويل). ثانيا، تم اشتقاق الأنماط الشهرية والموسمية والنتائج بينت باستخدام طريقة باسكويل أن صنف الاستقرار (C) لديه أعلى تكرار نسبي (RF%) في شهر كانون الثاني (28.72 %) ، وصنف الاستقرار (B) لديه أعلى نسبة تكرار نسبي (RF%) في شهر نيسان (33.98%)، ويتمتع صنف الاستقرار (C) بأعلى تردد نسبي (RF%) في تموز (64.74%)، وصنف الاستقرار (C) لديه أعلى نسبة تكرار نسبي (RF%) في شهر تشرين الاول (35.48%).

1. Introduction

Frank Pasquill proposed a method in 1961 [1] for classifying atmospheric stability based on common surface observations like wind speed, cloud cover, and the strength of incoming solar radiation in order to determine the degree of dispersion of small particles carried by air in the lower atmosphere layer. The technique soon gained popularity and is currently used in disciplines like meteorology and computations of atmospheric dispersion [2][3]. Later, Gifford changed these classes into a more functional form [4]. The identification of stability conditions is also necessary for the forecasting of vertical turbulence intensities, which are typically utilized to assess the dispersion of pollutants. There are mainly six atmospheric stabilities designated as A (extremely unstable), B (unstable), C (slightly unstable), D (neutral), E (slightly stable), and F (extremely stable). Later, stability G is also included to represent low wind night-time stable conditions [5].

The estimation of net radiation from solar altitude, cloud cover, and ceiling height was made possible by Turner by adding one more stability class to the PG scheme [6]. Afterward, the Pasquill-Turner Strategy (PTM) ordered air security with unmistakable files in light of perceptions of wind speed, sun-powered height point, and the hour of day [7]. When comparing several different stability schemes to determine which best represents the atmosphere's diffusion capability for a given location, Mohan and Siddiqui (1998) discovered that there is a wide range of stability types that are possible for the various surface wind and sky conditions corresponding to each individual Pasquill stability class. The introduction of the security classes has also diverged from various procedures in districts with additional marvelous scenes [8]. Estimates of stability were found to be well correlated with stable cases overland in Erbrink and Scholten's (1996) evaluation of the Pasquill stability scheme's performance near a coastline [9]. In order to determine the concentrations of pollutants in the city of Lanzhou in China, which is located in a river valley and is surrounded by mountains, Wang (1992) makes use of the classes. He discovers significant discrepancies between other stability estimates and the Pasquill stability classes [10].

The aim of this study is to find the spatial and temporal distribution of diurnal stability class's frequency according to Pasquill –Turner method, and find out the prevailing (high frequency) stability class for the selected areas within Baghdad province, for seasonal stability classes domain. Find relationship between atmospheric parameter such as wind speed, with behaviour frequency stability classes. Which is important in urban planning for cities, construction of facilities and power stations, and the spread of pollutants.

2. Location:

Baghdad is the largest and most heavily populated city in Iraq with an area of about 900 Km^2 , whereas the total area of Baghdad Province reaches 5159 Km^2 , The estimated population is in the order of 6 million , Baghdad lies in the middle east of Iraq within the Mesopotamian Plain. The Tigris River passes through the city dividing it into two parts; Karkh east of the Tigris (Kadhimiya, Al-Shula, Al-Mansour, Al-Karkh, Green Zone, Al-Rasheed and Al-Dora) and Rasafa west of the Tigris (Al-Sha`b, Adhamiya, Al-Sadr 1, Al-Sadr 2, Al-Rusafa Al-Ghadir, Baghdad Al – Jedeeda and Karada), Maps of Baghdad, particularly those created by the Baghdad Environment Directorate, show that urbanized, agricultural, and industrial areas account for 72.69 percent, 25 percent, and 2.31 percent of the total area, respectively. [11]. The climate of Baghdad Province is considered to be semi-arid to dry, with cold winters, short springs and long, dry and very hot summers, with an average annual rainfall of about (140 mm) and no rain in summer, and an average temperature of (25 ^{o}C) over the past thirty years [3].

3. Data:

The Atmospheric Science Data Center (ASDC), which is part of the Science Directorate at the NASA Langley Research Center (LARC) in Hampton, Virginia, provided the majority of the meteorological data. The Data Center was established in 1991 to support the Earth Observing System (EOS) as part of NASA's Earth Science Enterprise and the U.S. Global Change Research Program. It is one of several Distributed Active Archive Centers (DAACs) sponsored by NASA as part of the Earth Observing [12].

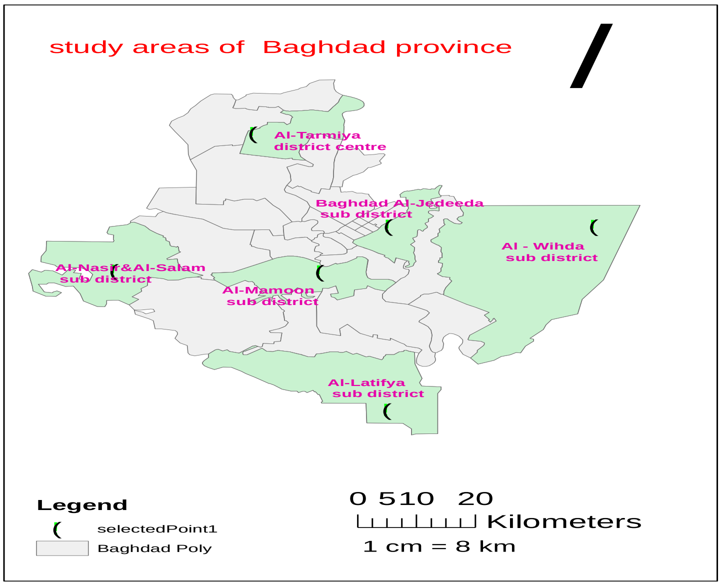


Figure 1: Baghdad province and locations of study stations grid

The data were chosen for the year 2018 and worked out by finding the temporal and spatial effects of the most diurnal frequent stability classes on some atmospheric and dynamic variables. Baghdad province was divided into a group of points with latitude and longitude, and six points were chosen to be distributed in a way that represents all regions of Baghdad province, as shown in Figure (1) and Table (1). utilizing the data of wind speed and the intensity of total solar radiation reaching the Earth's surface, as well as the Pasqual table for stability, through the daily hourly data for the months of January, April, July, and October, which represent winter, spring, summer, and autumn, respectively.

(It was done by the researcher using ArcGIS software.)

Table 1: Latitude and longitude and studies regions names

Name	Lat.	Long.
Al - Latifya sub district	32.875	44.5
Baghdad Al - Jedeeda sub district	33.375	44.5
Al - Tarmiya district centre	33.625	44.25
Al - Mamoon sub district	33.25	44.375
Al - Wihda sub district	33.375	44.875
Al -Nasir & Al -Salam sub district	33.25	44

4. Methodology

The most common method for determining the atmospheric stability classes is to assume that stability in the layers close to the ground is dependent on net radiation as an indicator of convective turbulence and wind speed at 10 meters as an indicator of mechanical turbulence [13]. Pasquill used common surface meteorological data like wind speed, solar radiation, and surface cloudiness to describe atmospheric stability. Then, in Table 2, he came up with six categories, from A (extremely unstable) to F (stable) conditions. This should be possible regardless of the mathematical conditions, not the files and tables used to determine these classes. [14], Table 3. The Pasquill-Turner Technique (PTM) depends on a design by Pasquill that has been surveyed by Turner (1964) and presents approaching sunlight-based radiation as far as the sun-powered rise point, cloud sum, or cloud level. Seven distinct categories are used to categorize atmospheric stability [15]. Additionally, PTM can basically be modified to demonstrate that it is utilized uniformly to register soundness in the table [16]. In any case, these standards order Pasquill classes as displayed in Table 3 [15]. Utilizing the programs ArcGIS 10.2 and Origin 2021 as tools for analyzing and drawing frequency atmospheric stability class data and identifying specific Baghdad province regions.

Table 2: the Pasqual stability classes and the stability requirements that go along with them [16].

CLASS	Description	CLASS	Description
A	Extremely unstable	D	Neutral
B	moderately unstable	E	Slightly stable
C	Slightly unstable	F	Moderately stable

Table 3: Based on surface wind speed and sky conditions, a method to determine each Pasquill stability class [1].

	Daytime insolation			***Night-time conditions***	
Surface wind speed (m/s)	**strong**	**Moderate**	**Slight**	**Thin overcast or > 4/8 low cloud**	**<=4/8 cloudiness**
<2	A	A-B	B	E	F
2-3	A-B	B	C	E	F
3-5 *5-6*	B	B-C	C	D	E
>6	B	B-C	C	D	E

Notes: Incoming solar radiation: Strong (>700 Wm^{-2}), moderate (350-700 Wm^{-2}), slight (< 350 Wm^{-2})

Table 4: Show Pasquill-Turner Method (PTM) of stability Scheme [6]

Stability condition	Pasquil-Gifford	PTM
Extremely unstable	A	1
Unstable	B	2
Slightly unstable	C	3
Neutral	D	4
Slightly stable	E	5
Stable	F	6
Extremely stable		7

In this study, the diurnal atmospheric stability classes were found within the boundary layer by using the Pasquel-Turner method using wind speed data and the intensity of solar radiation falling on the surface of the earth as shown in Table 4, through data taken from the existing Atmospheric Sciences Data Centre (ASDC) in (NASA) Langley center (LaRc) during daylight hours (6, 9, 12, 15, 18) for the months of January, April, July, and October of the year (2018) and for selected areas of Baghdad province, which included Al-Latifya sub district, Baghdad Al - Jedeeda sub district, Al- Tarmiya district center, Al- Mamoon sub district, Al- Wihda sub district, and Al-Nasir & Al-Salam sub district, extracting the highest frequency rate for the weather stability classes, and also classifying the selected areas according to the stability class, the highest frequency temporally and spatially, and also testing the relationship of some atmospheric and dynamic variables and their impact on the stability class in the study areas, as well as Evaluation of the Pasquel-Turner method for determining atmospheric stability classes.

4.1 Diurnal Max. RF% of stability classes distribution According to Pasquill method for selected region in Baghdad Province:

By applying the Pasquill method to the analysis of data on wind speed and solar radiation intensity for the months of January, April, July, and October of 2018 for the study areas, identifying the stability classes with the highest relative frequency percentage, and determining the relationship between average wind speed and the correlation coefficient (R), Figure 2 demonstrates that, in April, class A (extremely unstable conditions) was the most prevalent (15.95 percent) in the Baghdad Al – Jedeeda district (southeast of Baghdad). Figure 3 demonstrates that the relationship between the frequency of the stability class (A) and the average wind speed is inverse (R = -0.62) because the wind speed decreases in this region (2.7 m/sec) and is unaffected by the prevailing winds during this month [17].

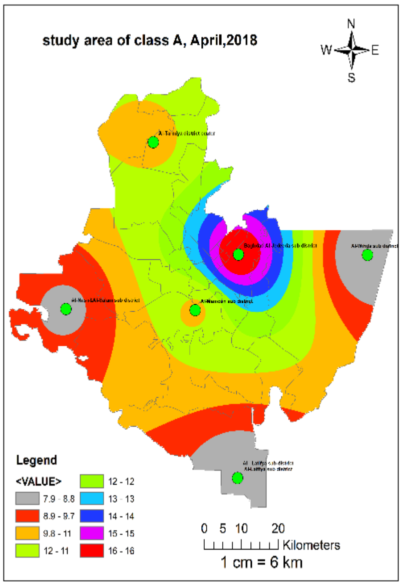
Figure 4 shows that class (B) (tolerably unsound circumstances) is the most successive in the Al-Tarmiyah and Al-Mamoun sub-areas (north and west of Baghdad) (33.98%) during April. Figure (5) demonstrates that the relationship between the frequency of the stability class (B) and the average wind speed is inverse (R = -0.90) and that it is also directly affected by the prevailing winds in this month [17]. As a result, it is evident that this result has been reached. The wind speed decreases in this region (2.7 m/sec).

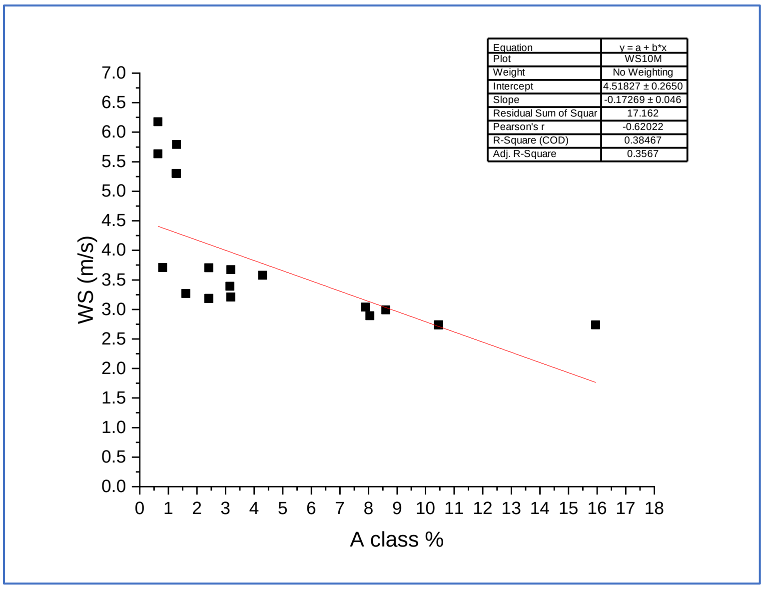
Figure 6 demonstrates that in the Baghdad Al – Jedeeda, Al-Tarmiya, and Al-Mamoun districts (East, North, and Central of Baghdad Province, respectively) during July, class (C) (slightly unstable conditions) is the most prevalent (64.74%). Figure (7) demonstrates that the wind speed increases in this region (5.30 m/sec), that there is a positive relationship between the frequency of the stability class (C) and the wind speed (R = 0.91), and that the wind speed is also directly influenced by the prevailing winds in this month [18].

Figure 8 shows that class (D) (unbiased circumstances) is the most successive in the Al-Nasr and Al-Salam area (West of Baghdad Region) (29.48%) during July. Figure 9 shows that the wind speed rises in this area (6.17 m/sec), that there is a positive relationship between the frequency of the stability class (D) and the average wind speed (R = 0.78), and that the wind speed is also influenced by the current winds in this month [17]. as displayed in Table 5:

Table 5: maximum percent of classes stability for selected stations

Class	Max	location	month	Correlation coefficient
A	15.95%	Baghdad Al- Jedeeda sub district	April	-0.62
B	33.98%	Al - Tarmiya district centre Al - Mamoon sub district	April	-0.90
C	64.74%	Baghdad Al - Jedeeda sub district Al - Tarmiya district center Al - Mamoon sub district	July	0.91
D	29.48%	Al -Nasir & Al -Salam sub district	July	0.78
AB	15.43%	Al - Latifya sub district	April	-0.89
BC	18.08%	Baghdad Al - Jedeeda sub district Al - Tarmiya district center Al - Mamoon sub district	January	-0.69
CD	8.06%	Al - Wihda sub district	October	0.11

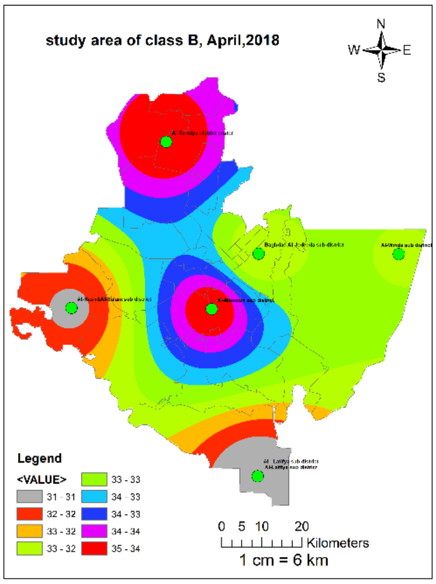




(a) **(b)**

Figure -2 stability condition at April

month-2018 (a) spatial distribution of frequency stability class A for six stations, (b) relationship between wind speed and frequency of stability class A



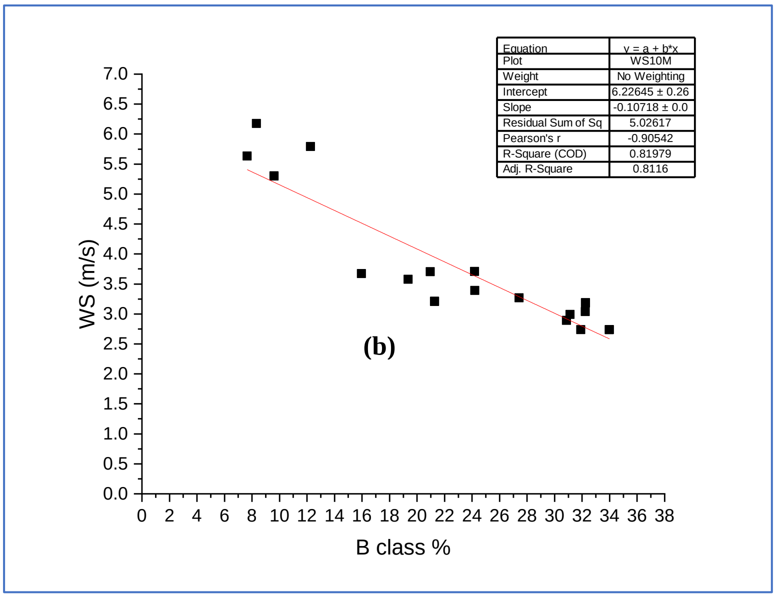
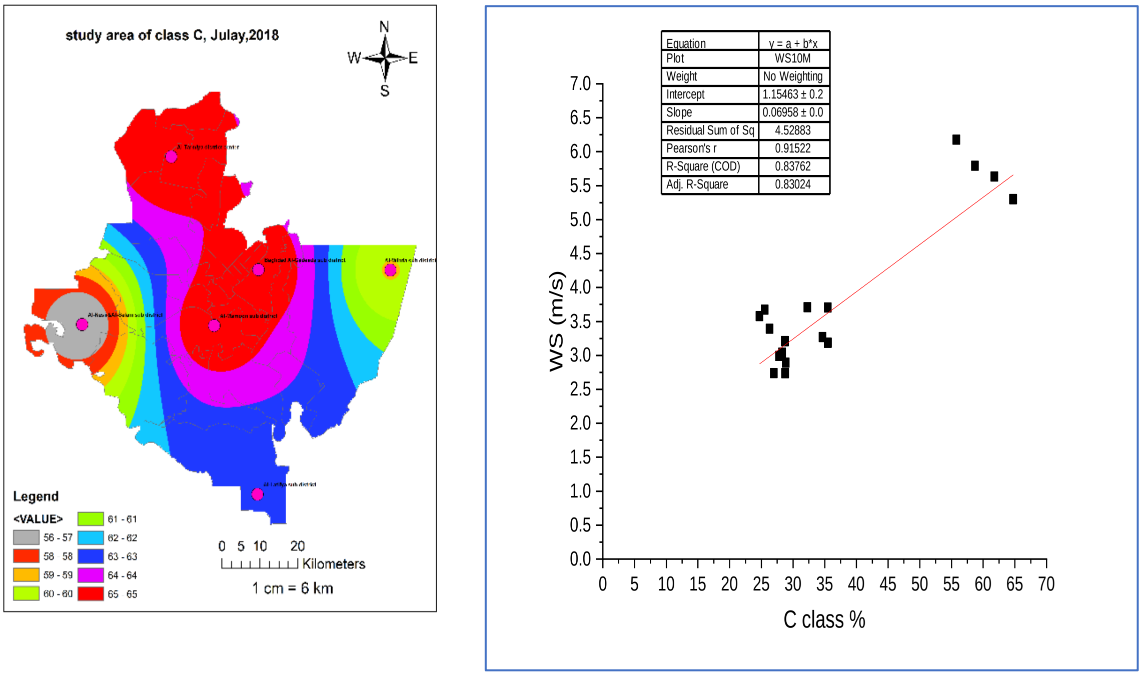


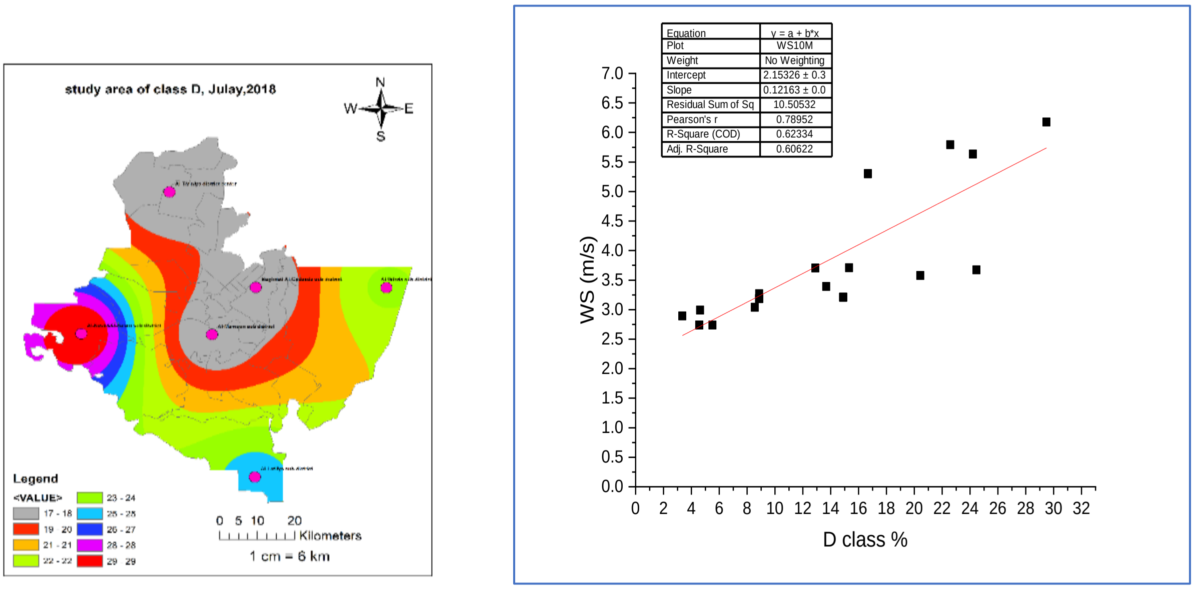
Figure -3 stability condition at April

l month-2018 (a) spatial distribution of frequency stability class B for six stations, (b) relationship between wind speed and frequency of stability class B



(a) **(b)**

Figure 4: stability condition at July month-2018 (a) spatial distribution of frequency stability class C for six stations, (b) relationship between wind speed and frequency of stability class C



(a) **(b)**

Figure 5: stability condition at July month-2018 (a) spatial distribution of frequency stability class D for six stations, (b) relationship between wind speed and frequency of stability class D

4.2 Distribution the diurnal relative frequency RF% of stability classes according to combining Pasquel-Turner method:

Through the figures 10 -12 the relationship of the highest relative frequency RF% of stability classes with average wind speed, we notice that the relationship is inverse and with a correlation coefficient (R = - 0.89, - 0.69, 0.11), respectively. It appears from the above Figures (10,11,12) that combining classes or merging classes leads to a weak relationship or a lack of clarity in the relationship between the frequency of stability classes and the rate of wind speed as in the Figure 6. This is due to the fact that Table 6 on which the classification was based Pasquill -Turner depends on the neutral or near-neutral classification on the amount of clouds and the time of sunset or sunrise (The Pasquill-Turner Method (PTM), introducing incoming solar radiation in terms of solar elevation angle, cloud amount or cloud height) as additional factors for the effect of wind speed and the solar radiation intensity for Pasquill method, which made the relationship weak or unclear due to the multiplicity of influencing factors (non-linear)

Table 6: Relationship between Pasquil- Gifford and Pasquel-Turner method according to study calculation.

Diurnal Stability condition	Pasquil-Gifford	PTM	Combining Pasquel-Turner method
Extremely unstable	A	1	A1
Unstable	B	2	B2
Slightly unstable	C	3	C3
Neutral	D	4	D4
Extremely unstable - Unstable	AB	1.5	AB1.5
Unstable - Slightly unstable	BC	2.5	BC2.5
Slightly unstable - Neutral	CD	3.5	CD3.5

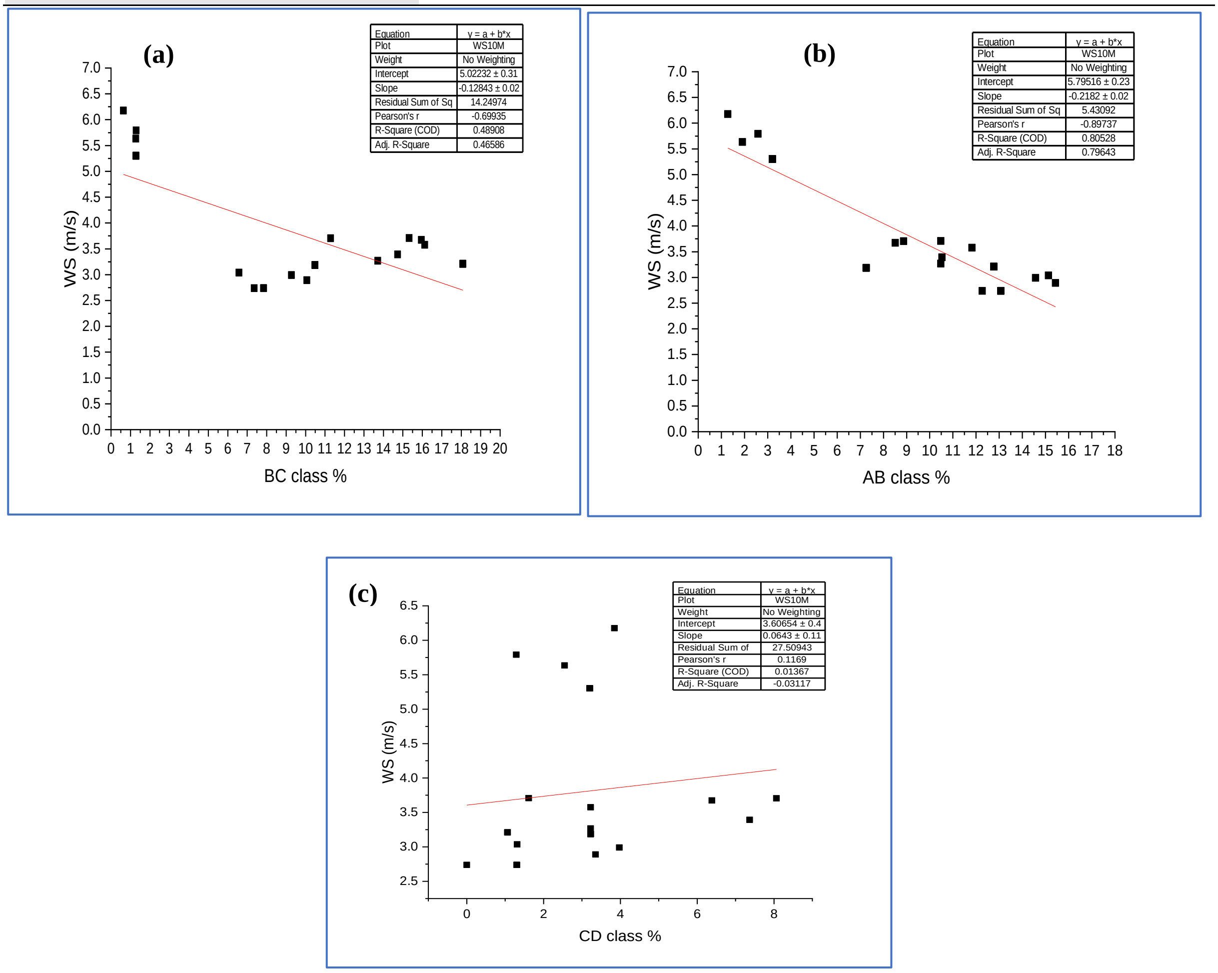


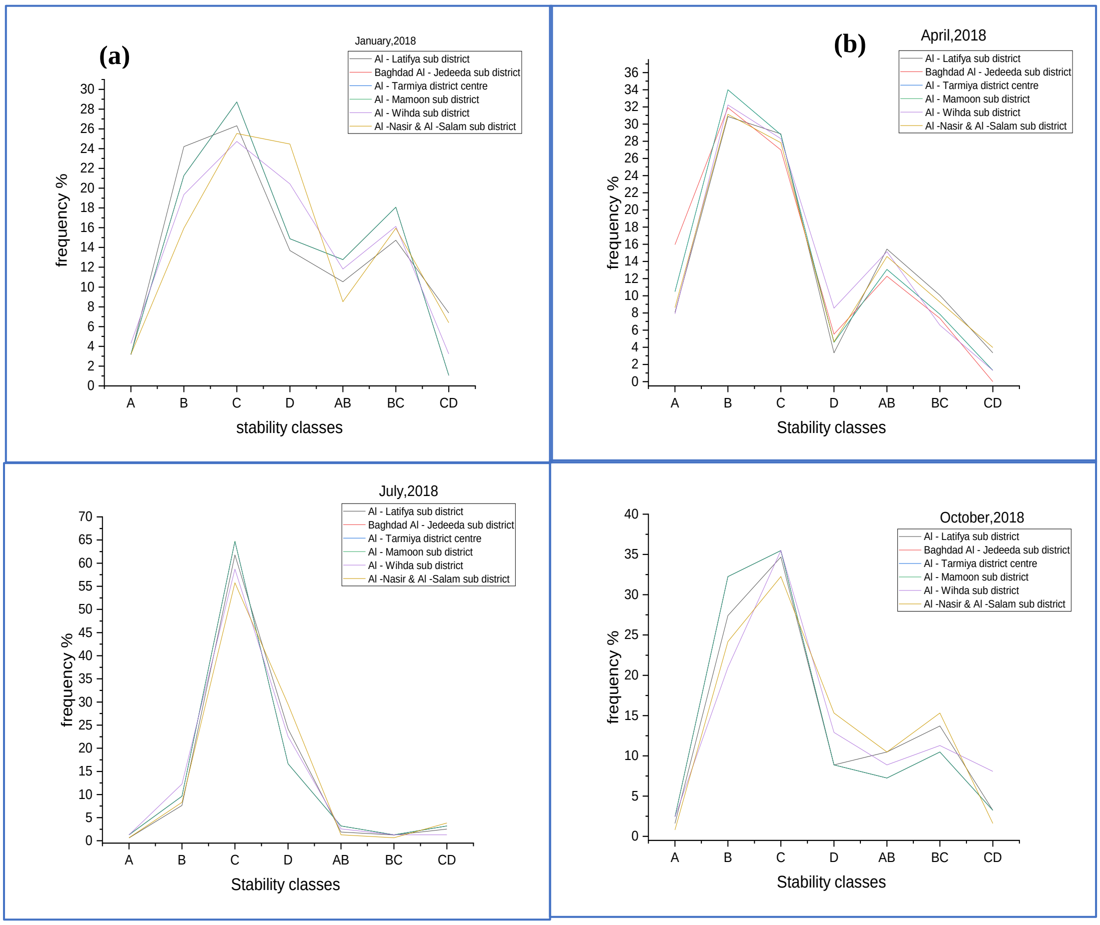
Figure 6: Relationship between wind speed recorded and stability classes AB, BC and CD frequency

4.3 Seasonal distribution of diurnal Max. RF% of stability classes According to Pasquill method and the prevailing WS:

For selected areas within Baghdad Province for the months (January, April, July, October) of 2018, it was found that the Max. RF% during January is the stability class (C) with a value of (28.72%) in the districts (Baghdad Al – Jedeeda, Al-Tarmiya, Al-Mamoun) and the prevailing winds speed in this month increase to reach (5.30 m/sec) Figure 7a. In April, the Max. RF% was in the stability category B with a value of (33.98%) and for the districts (Al-Tarmiyah, Al-Mamoun) and the prevailing winds in this month decreases in this region (2.7 m/sec) Figure 7b. In July, it was found that the highest frequency rate was in the stability category (C) with a value of (64.74%) for the sub-districts (Baghdad Al-Jadida, Tarmiya, Al-Mamoun) and the prevailing winds in this month increases and reach to (5.30 m/sec) Figure 7c. In October, it was found that the highest frequency of the stability category was in the stability class (C) with a value of (35.48%) for the districts (Baghdad Al – Jedeeda, Tarmiyah, Al-Mamoun, Al-Wahda) and the prevailing winds in this month increases and reach to (3.7 m/sec) Figure 7d.

Table 7: Seasonal distribution of diurnal Max. RF% of stability classes According to Pasquill method

month	Max. class	value	location	analysis
January	C	28.72%	(Baghdad Al - Jedeeda & Al – Tarmiya & Al–Mamoon) sub district	Slightly unstable conditions
April	B	33.98%	(Al - Tarmiya & Al – Mamoon) sub district	Moderately unstable conditions
July	C	64.74%	(Baghdad Al - Jedeeda & Al – Tarmiya & Al–Mamoon) sub district	Slightly unstable conditions
October	C	35.48%	(Baghdad Al - Jedeeda & Al - Tarmiya & Al - Mamoon & Al - Wihda)sub district	Slightly unstable conditions



(c) **(d)**

Figure 7- Frequency percent distribution for stability classes for six stations in months (a) January, (b) April, (c) July and (d) October

4.4 Conclusion

In order to forecast vertical turbulent intensities and calculate the degree of dispersion of small particles carried by air in the lower layer of the atmosphere, it is essential to determine the conditions of spatial and temporal distribution stability.

The province of Baghdad was broken up into a group of latitude and longitude points, and six of those points were chosen to be distributed in a way that represented all of the province's regions.Using the Pasquill Method, the distribution of stability classes is as follows:
In April, classes (A) are most common in the Baghdad Al – Jedeeda district, and their frequency is inversely correlated with average wind speed (R = -0.62). In April, classes (B) are most common in the Al-Tarmiyah and Al-Mamoun sub-districts, and their frequency is inversely correlated with average wind speed (R = -0.90).

During the month of July, Class (C) storms are the most common in the Baghdad Al – Jedeeda, Al-Tarmiya, and Al-Mamoun districts, and they have a positive relationship with the average wind speed (R=0.91). In the Al-Nasr and Al-Salam district, Class (D) storms are the most common in July and have a positive relationship with the average wind speed (R = 0.78).

The non-linear multiplicity of influencing factors (The Pasquill-Turner Method (PTM) in additional factors for Pasquill method), introducing incoming solar radiation in terms of cloud quantity, cloud height, or solar elevation angle, results in a weak or unclear relationship between the relative frequency RF% of stability classes and the average wind speed (table 6). There is a clear correlation between the average wind speed and the atmospheric stability classes, where the wind speed rate can be considered a good indicator of the frequency of the prevailing stability class in the study area.

Using the Pasquill method, relative frequency RF% of stability classes was studied for the months of January, April, July, and October. It was found that the stability class (C) had the highest frequency in January, that the stability category (B) had the highest frequency rate in April, that the stability category (C) had the highest frequency rate in July, and that the stability category (C) had the highest frequency in October.

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