Repetitive Behaviour of Dust Storms in The Holy City of Karbala Governorate and their relationship to Some Weather Factors.

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Abstract

Dust storms are considered as one of the important weather phenomena that have harmful and negative effects on the environment in various aspects. They arise and occur frequently depending on multiple topographical and climatic factors. In this study, data from the Iraqi Meteorological organisation and Seismic Monitoring IMOS recorded at the Karbala metrological Station was used to test and examine the statistical behaviour of dust storms for the period from 1980-2022 by dividing those dust storms into severe, moderate, and light depending on the extent of visibility and the period the dust storm lasted. Studies compared the frequency of dust storms with the weather conditions, such as wind, rainfall and max and min. air temperature. The results showed that there was a decrease in the tendency for dust storms frequency by 9%, accompanied by a decrease in the recorded wind speeds to about 2% within the average speed of about 2.7m/s. As for rain alone, there was also a decrease in its trend's quantities by about 0.28 within the annual average for four decades, which reached 94 millimetres. On the other hand, max. and min. temperature records increased about 1C0, but this increase is part of global warming and doesn't affect dust storm frequency rate alone, but can be worked with other atmospheric elements. From the current results, we concluded that the frequency of dust storms in Karbala province is affected by the boundaries of the local governorate, and there are other factors which play a role in the statistical behaviour of the frequency in the

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occurrence of dust storms, which may be regional or global. The results can be used to give warnings to visitors heading to Karbala to take necessary precautions and prepare for the occurrence of dust storms in seasons of drought and lack of rain.

Keyword: Holy City of Karbala, Wind speed, Rainfall, max. min air temperature, Dust storm Frequency

Introduction:

Dust storms are weather events that occur near the surface, which are produced by wind destruction and the separation of deposit particles far from a surface (Middleton, 2017). Dust results initially in waterless or semi-dry locations, which accounts for some 33% of the surface of the Earth. In reality, the northern hemisphere produces about 90% of worldwide floating mineral dust, which will be likewise accumulated (Hassoon et al, 2021, Duce, 1995). Dust storms effect are seen on many fronts, reflected or scattered solar radiation leading to weakening the efficiency of the solar cell, causing a decline in communication and machine-driven apparatuses, and effecting air quality and therefore being responsible for harmful illnesses (Boğan et al, 2022). Iraq is situated in the northern part of the subtropic section; the Northwest winds govern most sections of the country for extensive times of the year (Hassoon and Roomi, 2023). The presence of Iraq to the east of the Mediterranean Sea means it is altered by the environment of this

zone throughout the winter, which gives slight rainfall during this period (Duce, 1995). In addition, the placement of Iraq close to the Arabian Gulf region allows for hot and moist winds supplemented by cyclones most of the time triggering the rise in dust particles in the air (Khudur, 2014). The climate of Iraq is categorized by semitropical, mainland, waterless to semi-arid. The heaviest rainfall is displayed in the mountainous regions, which are an essential water resource for Iraq. Main soil types that exist across Iraq are silt adjoining clays, which contain elements smaller than 70 μm in (thickness) and are easily transported via wind movement (Roomi, 2017). The main sources of the progression of dust storms in Iraq is climatic change specifically the extreme reduction in annual report rate of rainfall (Mohammed and Hassoon, 2019). Other details are genetic deviations, marshlands drainage, degradation of soil, the behaviour of farming, water possessions corrupt supervision which lead to reductions in green cover, desertification and scarcities which lead to the development of dust storms (Hassoon et al, 2021). Deficiencies and arid conditions add to the decline of soil grains, besides, wind also affects the presence of dust storms (Jassim et al, 2012, Al-Khudhairy et al, 2023). Many scientists and researchers deal with the study of dust storm behaviour in the middle and south region areas of Iraq. For example: Ibrahim I. Mohammed and Ahmed F. Hassoon (2019), used data (visibility, wind speed and direction and total rain amount) from the Iraqi Meteorological Organization and Seismology to investigate stations for middle and southern Iraq spread across the period from 2001 - 2017 to compare

annually the severity of dust storms during rainy seasons. It was determined that there was a converse association between rainfall and severe dust storms, and the lowest quantity of rainfall was in Nukhayb station 1304.6mm throughout the training period with 62 severe dust storms[9]. Asaad Sh. M. Alhesnawi et al (2019) , gathered samples of dust from March 2017 to February 2018 at three positions rural, urban and industrial to observe the monthly state of dust in Karbala, The results of this study discovered that the amount of dust falling ranged 9.66-96.04 g/m with average 36.47 g/m, most of which are of diverse and unequal shapes and the dimensions of dust particles ranged from 13.22-30.80 µm (Alhesnawi et al, 2019). Jaafar Hussain Hamad Al-Hamd, N. M. Alwan (2020) identified and categorised the delivery of green spaces associated to the total area of the city Centre of Holy City of Karbala, wherein the distribution of green spaces for each citizen was concluded to estimate the conservational quality of the city. Accordingly, the fall down dust was accumulated on dust collection tubes and measured at numerous sites, reviewing the usual winds and its relationship with the allocation of green spaces and the city's green belt design. The study applied the Normalized Difference Vegetation Index (NDVI) method to produce maps for the measures of dropping dust and current winds direction (Al-Hamd and Alwan, 2020). Aws A. Al-Khudhairy et al (2023) analysed and examined tendencies of numbers of dust storms and their conduct in thirteen meteorological stations. Blowouts all over Iraq for the period 30 years and trends of dust storms included monthly data of dust

storms existences which were analysed spatially and temporally using the linear regression method, and spatially epitomized by using ArcGIS (Khudur, 2014). Aws A. Al-Khudhairy and et al (2023) also explore sand and dust storms recognition in Iraq using Moderate Resolution Imaging Spectroradiometer (MODIS) data, both from Terra and Aqua satellite techniques for the year 2022. MODIS Surface Reflection Factor Daily L2G Global 1 km and 500 m data were employed to calculate the Normalized Difference Dust Index (NDDI), Normalized Difference Dust Index (NDDI) is utilized for the discovery of sand and dust storms (Al-Khudhairy et al, 2023). The aim of this study is to analyse and identify dust storms recorded in Karbala by weather stations installed in Karbala city for the past 40 years. The analysis considers frequency of occurrence, for light and sever dust storms, also periods of occurrence and time of occurrence; the study deals with the effects of some basic atmospheric elements on the activity of dust storm persistency, such as rainfall and wind speed.

2. Location

Karbala province is positioned southwest of Baghdad, 105 km westward of the Euphrates Waterway on the boundary of the Western Desert. The region is positioned at a longitude of 44.40 degrees and latitude of 33.31 degrees. It has an expanse of 5034 km2, which characterizes 1.14% of Iraq's region (438317) km2.

Three areas were selected in Karbala province; the first is a rural area, the second is an urban area and the third is an industrialized area (Al-Salman et al, 2021). Figure 1, show Karbala municipality relative to Iraq.

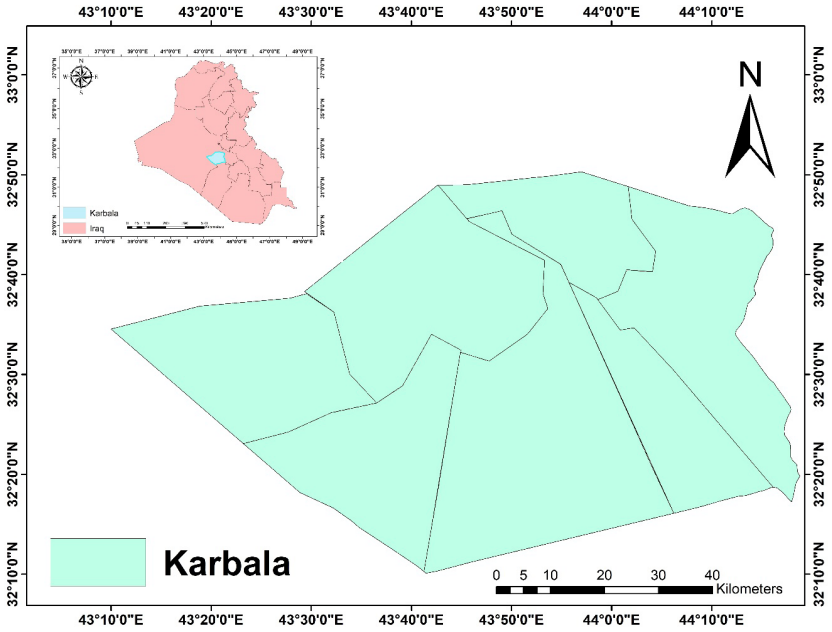

Figure 1: location Iraq and Holy City of Karbala

3. Data

After accumulating the data (Hourly, Daily, Monthly), from the Meteorological Organization and Seismology IMOS for wind speed and visibility, which are the most significant two elements to consider when studying the WMO arrangement of dust storms, we also gained rainfall data since several studies linked the decline of dust storms with rainfall and wind speed. In this study, a historic high of mainly dust storms data, containing monthly wind speed,

prevailing wind, rainfall, and number of dust storms, adjourned and rising dust were attained from the Iraq Meteorological Organization and Seismology (IMOS) for a 40-year period (1980-2022). Therefore, the interval of the investigation was chosen to be as lengthy as possible, dependent on the obtainability of recording data.

4. Dust Storms Classification

Dust storms will be classified and categorized into three groups[16] [9] [10]:

1. Light Dust Storm illustrated as a storm with distinguishability ($0.5 <$ visibility < 1) km, and speed of wind ($8 <$ wind speed ≤ 10) m/s.
2. Moderate Dust Storm illustrated as a storm with discernibility ($0.2 <$ visibility ≤ 0.5) km, and speed of wind ($8 <$ wind speed ≤ 12) m/s.
3. Severe Dust Storm considered as a storm with visibility ($0 \leq$ visibility ≤ 0.2) km, and speed of wind ($8 <$ wind speed ≤ 18) m/s.

5. Result and discussion

5-1 Dust Storm frequency

The recurrence of dust storms in a specific area is considered one of the most important indicators of a change in the atmospheric system or in the topographic layer of the Earth's surface. In this study, an analysis of the frequency of occurrence of dust storms in Karbala Governorate was conducted, which was recorded through the weather station of the General Authority for Meteorology and

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Seismic Monitoring. As a case of examining the behaviour of dust storms, a period of more than 20 years was initially taken, which included hourly, monthly, and annual data for the occurrence of dust storms. In addition to testing the conditions of the dust storm, its intensity, and the hours of its stay, start, and end, the second paragraph of the analysis took a longer period of time, more than 40 years, to study the monthly behaviour of dust storm recurrence and compare it with some weather factors such as rain and recorded wind speeds. Figure No. 2 shows the frequency of dust storms during the sequence of a full month of 30 days for a period of 22 years for the Holy Karbala station, as the number of days in the month on average is 30 days. From the figure we notice that the most frequent occurrence of dust storms during that period was limited to the sequence of days in the middle of the month, especially Day 17, while the sequence of days 10 and 23 are the least frequent days for the occurrence of dust storms, and this may be because the middle of the months is the real period

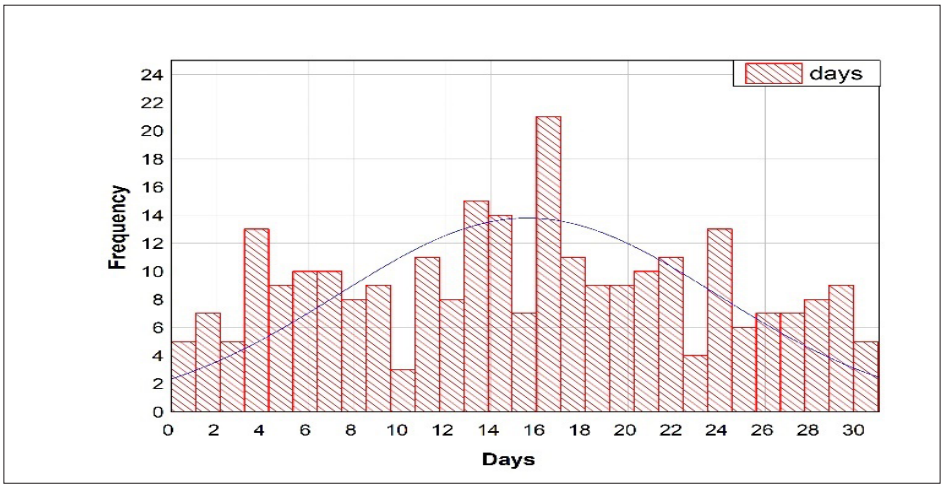

Figure 2: Daily frequency of occurrence dust storm through period 2000-2022 in holy Karbala

that shows the nature of the prevailing and dominant weather current and that the days at the ends of the months are a transitional state. Figure 3 shows the monthly distribution of the frequency of dust storms, where it was noted that the highest monthly frequencies were in the months of April and May, while the lowest frequency of dust storms was in the months of December and January. This is due to the state of drought and the extreme increase in temperatures in addition to wind activity during this period causes erosion and an increase in the amounts of suspended dust particles. The case of an increase in the activity of recurring dust storms can be due to the synoptic conditions associated with the prevailing atmospheric pressure systems, in addition to the formation of air fronts, and these accompanying conditions have been confirmed in their existence, through studies of weather conditions by many researchers.

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Figure 4 shows the annual frequency of dust storms, where it was found that the years from 2008 to 2010 had very high frequencies of dust storms and much higher than the general average. The change in the frequency of occurrence of dust storms on an annual basis cannot be due to seasonal changes as a result of the Earth's rotation around the sun, but it can be due to the occurrence of decadal dry seasons associated with lack of rain due to the global circulation of the atmosphere, such as increasing surface temperatures of sea

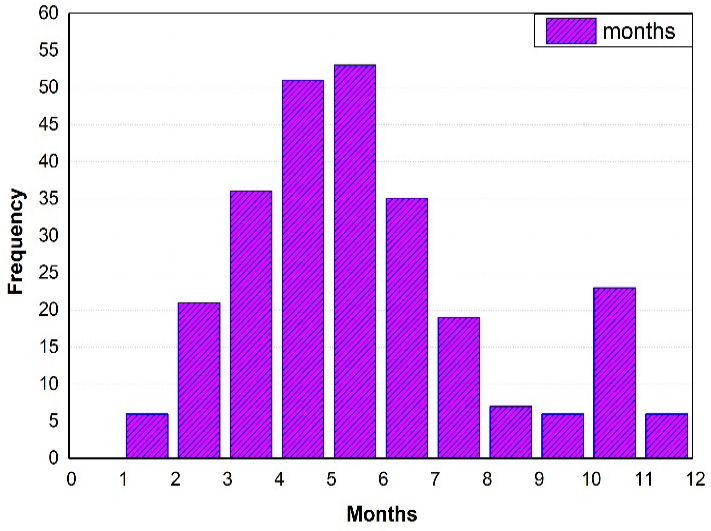

Figure 3: Monthly frequency of occurrence through period 20002022- in holy Karbala

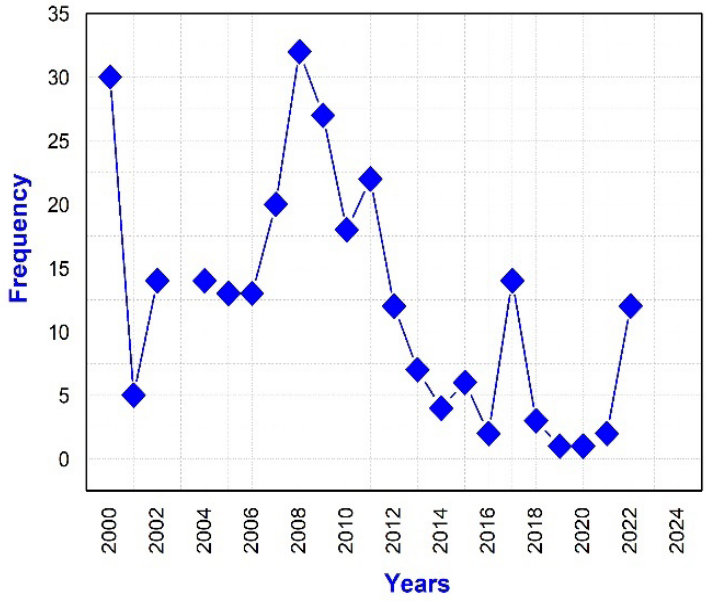

Figure 4: Yearly frequency of occurrence through period 20002022- in holy Karbala

water or oceans in certain areas and their decrease in other areas, which is known as the Lena and La Nina phenomenon. These phenomena work to redistribute the amounts of rain and evaporation from the seas and oceans.

5-2 Light and Sever dust storm

In addition to the recurrence of dust storms during certain periods, they also vary in intensity and according to many factors operating within the atmosphere and its interaction with the Earth's cover. During the current study, cases of dust storms recorded at

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the Holy Karbala station were classified into light or moderate dust storms and severe dust storms, and the classification criterion used here relied primarily on two factors: the concentration and spread of dense dust particles, which is expressed by the range of vision and is inversely proportional to the dust concentration. The second factor is the observed wind speed. It is possible to review paragraph 4 in the theoretical part and view it. Figures (5) and (6) show the frequency of the duration of hours of survival of severe and moderate dust storms, as it was noted that about 40% of the dust storms that strike Karbala Governorate are severe dust storms whose duration of stay exceeds about 12 hours, although their frequency is very small. However, they have fairly good and certain rates and last up to 9 hours. See Figures 5 and 6 and compare them in terms of values and frequency. We note that mild ones have fewer hours of survival compared to severe ones. Severe dust storms are mostly not of local origin. They arise within large areas of the world and move over long distances, but they intensify or weaken according to the topography of the region and the weather condition. Figure 7 shows the recommended hours for severe and moderate dust storms to occur within a 24-hour period within Karbala Governorate, as most of the light and severe dust storms occur more often at the beginning of the day at sunrise hours and the increase in thermal heating of the Earth's surface, as this heating works to fuel the dust storm. Through the formation of the local convective boundary layer, the early morning hours have the highest growth speed of the convective boundary layer,

according to the source (Kareem and Hassoon, 2023).

Therefore, we expect the activity of dust storms to intensify during the daylight hours, while the activity and frequency of their occurrence at night hours will be weak due to the formation of the nocturnal limiting layer close to the Earth's surface, which works to reduce the movement of air bands, (Hassoon and Roomi, 2023) and thus the dust storm does not have the possibility of feeding and reactivating, and thus resuspension of dust particles, but rather there will be downward movement and deposition of dust particles due to atmospheric stability during these hours.

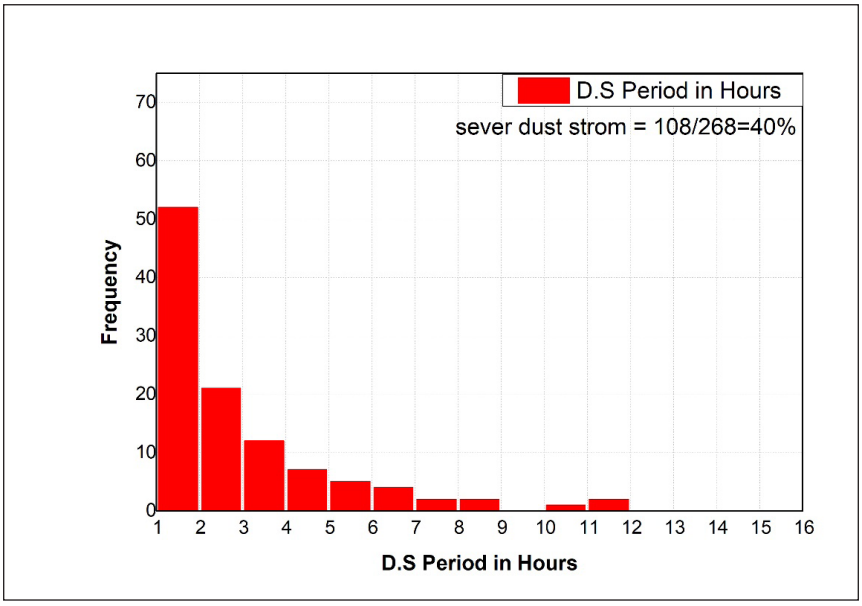

Figure 5: Frequency of Occurrence hourly period for severe dust storm for Karbala station during period 20002022-

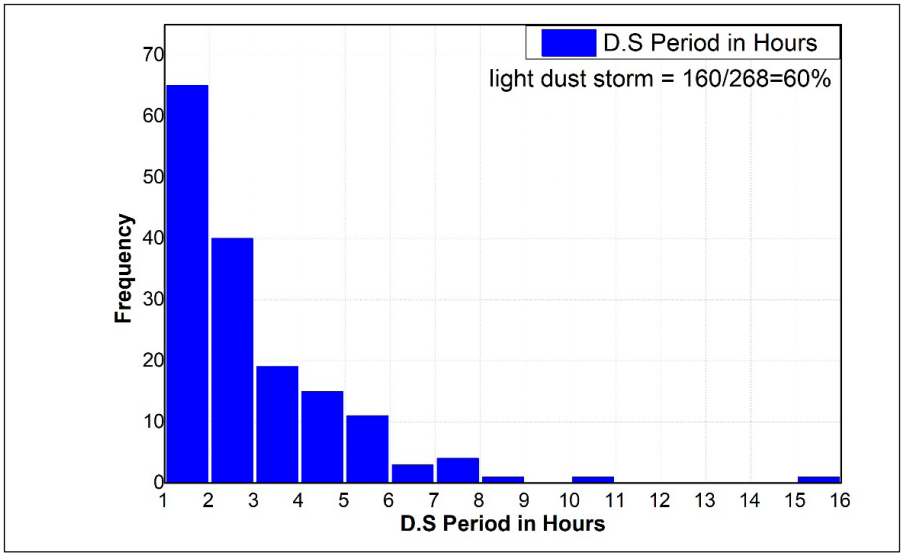

Figure 6: Frequency of Occurrence hourly period for light and moderate dust storms for Karbala station during period 20002022-

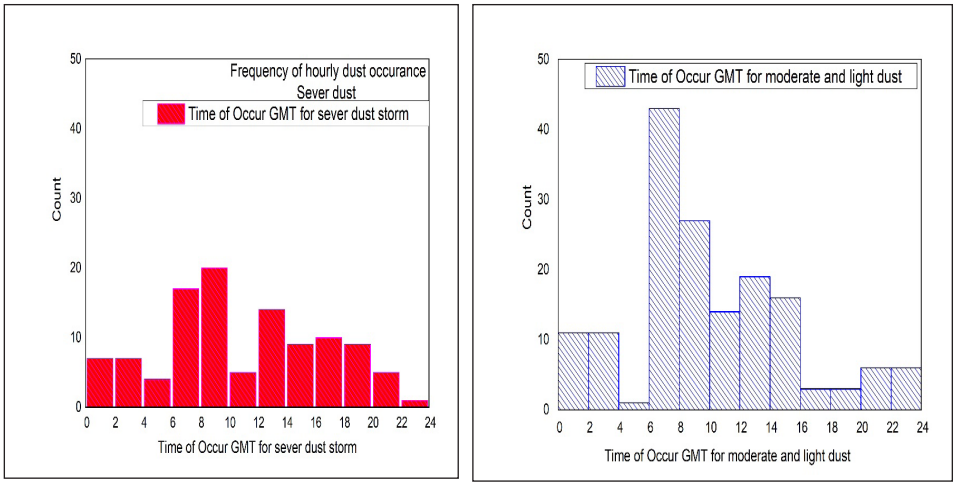

Figure 7: Frequency of Occurrence daily period for (a)light and moderate and (b) severe dust storm for Karbala station at period 20002022-

4-3 Effect of Atmospheric Element on Dust Storm

Weather factors affect the behaviour of dust storms fundamentally, and any change in the behaviour of atmospheric systems often has an impact in increasing or decreasing the frequency of severe and light dust storms recorded at weather monitoring stations. This fact has been proven in many solid scientific research. The current paragraph deals with comparing the rate of behaviour of recurrence of dust storms over long periods extending up to four decades with the rate behaviour of some important atmospheric parameters in relation to the emergence and development of dust storms, which are falling rain and the prevailing wind speed, see Figure 8. The observed values of atmospheric parameters are not significantly

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related to the current atmosphere. For Karbala Governorate, where most of the weather conditions accompanying dust storms are directly related to the synoptic condition prevailing over Iraq and the region in general, but there is some specificity to the local climate of the governorate. Most of the increase in the frequency of dust storms, as we saw in Figure 4, occurred in the years 2008 and 2010 in Iraq in general and in Karbala in particular, in contrast to what was in previous years before 2003, in which the frequency of dust storms was relatively low. And this is also the case in the last years of 2020, Figure 4 and also Figure (8a) show the frequency distribution rates of dust storms recorded during a period of 40 years from 1980 to 2022. These large time periods were divided into small decadal periods in order to study the recurrence behaviour of dust storms every ten

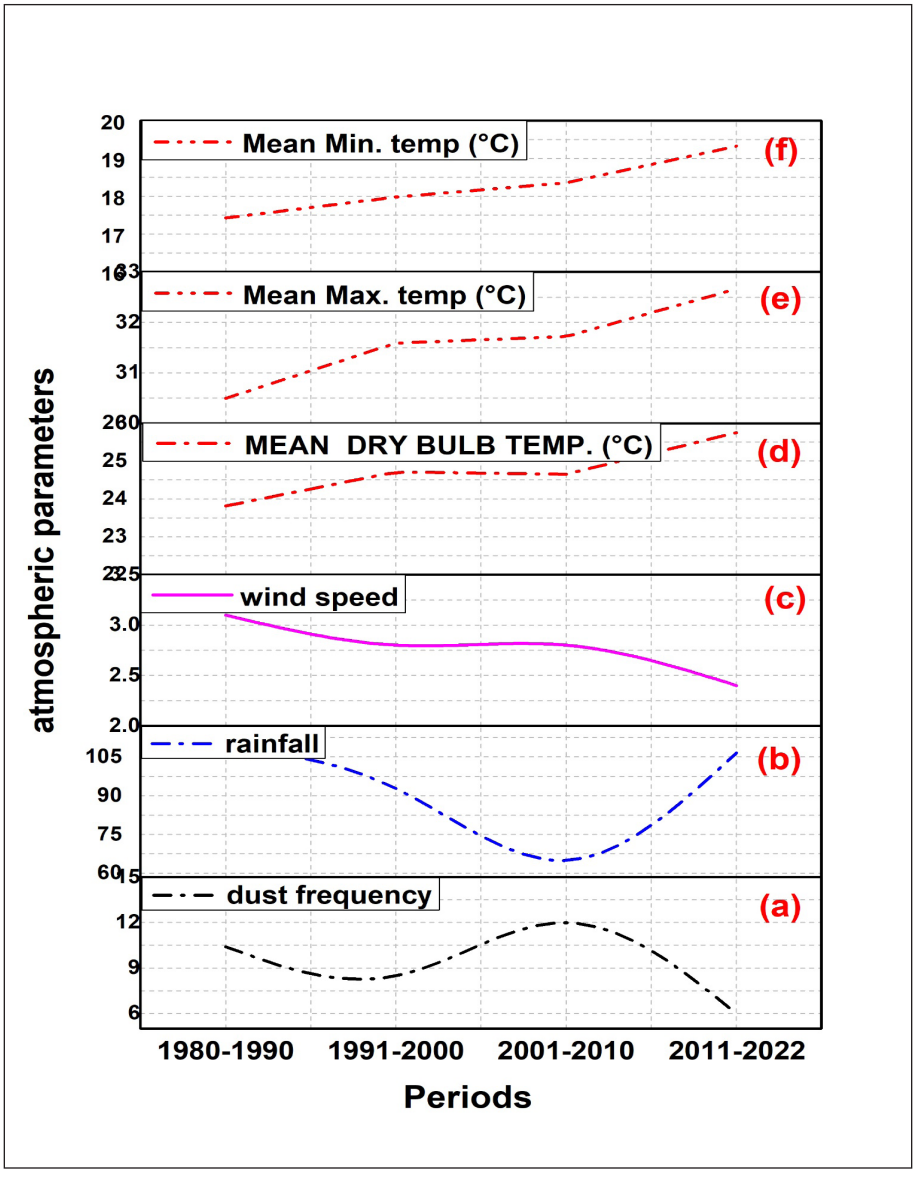

Figure 8: show the trends average of (a) trend frequency of dust storms, (b) average tends of rainfall (c) average trends of wind speed

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consecutive years separately. The frequency rate of dust storms in the first period was higher than the overall average by only one value. In the second period, the second decade, there was a decrease in the values of recorded recurrent storms by about 0.69 percent of the general average. Figure 8. The third decade from 2000 - 2010. It was recorded that there was a significant increase in the number of dust storm recurrences, reaching 160% of the general average for the four decades, while it was There is a decrease in dust storms recorded during the last decade from 2010-2020, reaching 64.8% of the general average. The general tendency for dust storms to recur during the past 42 years witnessed a decrease in the frequency of dust storms by a rate of up to 9%, with an overall average frequency of dust storms of about 9.5 times during that period.

4-3-1 Rainfall

Drought greatly affects the frequency of occurrence of dust storms due to the lack of rainfall. The current study took it upon itself to divide the study periods into decadal periods, where rain rates were dealt with over a period of ten years and compared with the frequency of dust storms. The average amount of rain falling on the Karbala station over a period of more than 40 years was 95 millimetres, and this amount is considered a general average rainfall, which is the amount of rain collected on a monthly basis within the five rainy months of the winter, spring, and fall seasons. During the first decade, 1980-1990, there was an increase in the amount of rain above the general average by about 16 mm, while

there was a decrease of 2 mm in the amount of rain in the second decade, 1990-2000. The size of the decrease was relatively large in the period 2000-2010 and amounted to About 29 mm. This period witnessed a significant and noticeable increase in the frequency of dust storms. Also note Figure 4 and Figure 8 b, that the last period extending from 2010 - 2020 witnessed a noticeable improvement in the volume of precipitation, reaching 13 mm.

4-3-2 Wind speed

The prevailing winds in Iraq are north-westerly, as wind speed is considered an important factor in the formation of dust storms, as the increase in wind speed causes dust particles to rise and form a dust storm. In the same way that was used in analysing rates of rainfall amounts and comparing them with the frequency of occurrence of dust storms, wind speed rates were calculated in each of the four decades and the result of the increase and decrease in wind speed rates was compared with the rates of storm recurrence every ten years separately. The relationship between them is shown in Figure 8c, which indicates that wind speeds in the first decade 1980-1990 increased above the general average by about 0.4 meters per second, and when comparing wind data and data on the frequency of dust storms, we also notice an increase in the frequency of dust storms to about 0.9 meters per second above the general average. The resulting condition matches the physical behaviour of the causes of the emergence of dust storms, in that the formation of dust storms requires the presence of relatively high

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speeds that sometimes reach, according to references, 8 meters per second. In the second and third periods, wind speeds remained slightly higher than the general average, at 0.1 meters per second. In contrast, in the third period, there was a significant increase in the frequency of dust storms during that period to more than 6 times the frequency of the general average. The latter case cannot be explained based on an increase in wind speeds, but there is another factor that may have a more obvious effect, which is the decrease in rain rates, rainfall records were relatively few during this period, and this period is considered a dry season. Also, the human factor can have a role in explaining it, that being the significant increase in dust storms recorded due to military operations after 2003. In the last decade, there has been a decrease in dust storms, accompanied by an increase in recorded rainfall amounts above the working average.

4-3-3 Maximum and Minimum Air Temperature

Increasing the temperature leads to an increase in the amounts of surface evaporation and thus increases the conditions of prevailing drought conditions, and thus the surface soil loses proportions and an important factor for its cohesion, which is moisture. By analysing the minimum and maximum surface temperatures and average air temperatures recorded at the Karbala station during the past four decades, we noticed an increase in the recorded temperature values, as the highest values of increase were in the last decade 2011 - 2022 from 24.7 to 25.7 for the average and from 31.7 to 32.7 for

the temperature. The maximum temperature increased from 18.4 to 19.3 from the minimum temperature. The increase in surface air temperatures in Karbala Governorate is considered part of the general rise in the planet's temperature due to global warming. The increase in maximum and minimum air temperatures recorded in the governorate, especially during the last decade, did not lead to an increase in the frequency of recorded dust storms, despite the importance of the temperature factor in increasing droughts and increasing evaporation rates. This is due to the fact that the last ten years were a harvest season of sufficient proportions of rain, and drawings 8a, 8b, and 8d, e, and f can be compared to obtain the above result. We can conclude that the temperature factor is not essential in determining and predicting the increased frequency of dust storms in Karbala Governorate, but rather it is an auxiliary factor and works to influence the presence and frequency of dust storms with other factors such as amounts of rain, winds, and the synoptic weather condition.

5. Conclusion

1- The average daily frequency of dust storms recorded for more than 20 years, showing that most of the frequency of dust storms is concentrated in the middle of the days of the months during the period from 2000-2020. This result will be useful for visitors to the city of Karbala, as it is preferable for visiting times to be during the end and beginning periods of work.

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2- The monthly frequency of dust storms was limited to the months of April and summer due to drought during that period and high temperatures. Therefore, it is preferable to take masks and resources of protection from dust, as the times of the Arba'in visit to Imam Hussein (peace be upon him) were in the summer and spring months.

Most of the high frequencies of dust storms occur in the first hours of the day due to the conditions of convection and atmospheric stability prevailing during the day and night.

From the current results, we concluded that the frequency of dust storms in Karbala province is affected by the boundaries of the local governorate, and there are other factors that play a role in the statistical behaviour of the frequency of occurrence of dust storms, which may be regional or global. The results can be used to give warnings to visitors heading to Karbala to take necessary precautions and prepare for the occurrence of dust storms in seasons of drought and lack of rain.

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