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Full Length Article

Detection of the most frequent sources of dust storms in Iraq during 2020–2023 using space tools

Rafah R. Ismail [a,*], Saadiyah H. Halos [b], Bushra Q. Al-Abudi [a]

[a] *Dept. of Astronomy and Space, College of Science, University of Baghdad, Baghdad, Iraq*

[b] *Atmosphere and Space Sciences Centre, Directorate of Space Technology & Communication, Ministry of Sciences and Technology, Baghdad, Iraq*

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ABSTRACT

Dust storms are typical in arid and semi-arid regions such as the Middle East; the frequency and severity of dust storms have grown dramatically in Iraq in recent years. This paper identifies the dust storm sources in Iraq using remotely sensed data from Meteosat-spinning enhanced visible and infrared imager (SEVIRI) bands. Extracted combined satellite images and simulated frontal dust storm trajectories, using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model, are used to identify the most influential sources in the Middle East and Iraq. Out of 132 dust storms in Iraq during 2020–2023, the most frequent occurred in the spring and summer. A dust source frequency percentage map (DSFPM) is generated using ArcGIS software. The regions located in Iraq, Saudi Arabia, Syria, and Jordan are the largest dust storm sources. New dust sources are identified in Iraq's southwestern and western regions, such as Al-Nukhaib, Wadi Hauran, and Sinjar, along with new sources in Saudi Arabia, Jordan, and Syria. The most common sources are concentrated in Iraq (55.31%), mainly in the Tigris and Euphrates basin, western desert, and Al-Jazeera region, followed by Syria (19.55%), Saudi Arabia (12.29%), and Jordan (11.73%). The highest dust storm source frequency in Iraq is found in the Al-Samawa desert's southern region (27.37%). Also, the highest frequency of dust sources from each country is determined. Knowing the origins and trajectories of dust storms will enhance treatments of these causes and their consequences on the environment and socio-economics of the region. It contributes to the support of specialised regional agencies to mitigate this phenomenon.

1. Introduction

A dust storm is a meteorological phenomenon characterized by a solid and turbulent wind carrying significant dust particles. It typically occurs in arid or semi-arid regions where loose soil or dry, barren surfaces are prevalent, such as in the Middle East desert (Roomi et al., 2017). Dust storms can range in size and intensity from localized and short-duration events to large-scale, long-lasting storms that cover vast areas. They may affect human activity and the environment in several ways. They can cause visibility to drop to almost nothing, which puts road and aircraft traffic in significant danger (Shoemaker and Davis, 2008). People's health can be negatively impacted by dust particles in the air, especially those who have respiratory problems. Dust storms may harm crops and affect soil fertility (Tong et al., 2023).

A dust storm is defined by the World Meteorological Organization (WMO) as a solid, wind-driven occurrence that causes significant amounts of dry soil particles or other tiny, separated materials to be suspended and transported in the atmosphere, resulting in visibility of less than 1000 m (Middleton and Kang, 2017). Al-Haboob is another type of dust storm. It is a type of solid dust storm that occurs in arid and semi-arid regions and is typically associated with the outflow of a thunderstorm. It is characterized by a wall of blowing dust and sand that advances rapidly, often reducing visibility to a few meters or less (Ahmed, 2019). The WMO defines a dust devil as a small, well-developed whirlwind that lifts dust or sand vertically into the air. Dust devils typically form on hot, sunny days due to convective processes and are often observed in desert or open areas (Lorenz and Jackson, 2015). The high-pressure system is one of the mechanisms in dust formation. Dust masses form in various meteorological ways, especially in cold and warm seasons (Hamid, 2007). The strong wind frequently preceding clearly defined cold fronts can lift these dust particles, resulting in dust storms (Maji and Sonwani, 2022). Dust can be lifted both behind and even ahead of cold fronts, where winds often blow stronger behind a front than in front of it. One of the easiest ways to

* Corresponding author.
E-mail address: rafah.ismail@sc.uobaghdad.edu.iq (R.R. Ismail).

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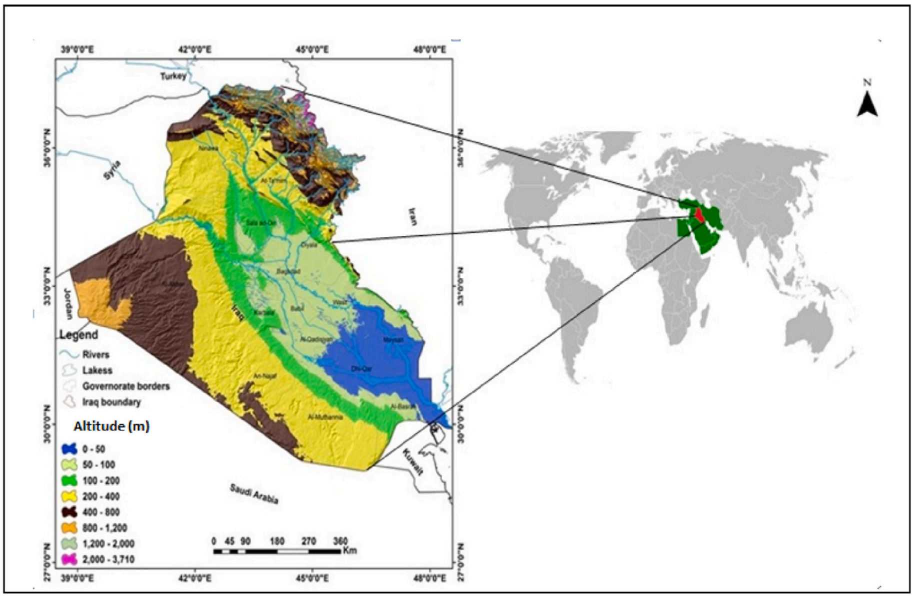

Fig. 1. Location of Iraq in the world map.

describe this seasonal tendency is as a hybrid of two weather systems. It combines two weather systems: the polar front jet stream moving down from the European continent and the sub-tropical jet stream pushing south of the Arabian Peninsula. The weather in this area is significantly more dynamic when these two systems approach together, mainly the solid northwesterly winds (Ding and Sikka, 2006). Strong winds are required to lift the larger dust particles into the air, and there must also be a significant amount of vertical motion for long-range transport (Van Der Does et al., 2018). Soil moisture is another element that affects dust storms; slight rainfall can prevent dust from entering the atmosphere (Middleton and Kang, 2017). Dust storms are the most noteworthy natural hazard in Iraq and surrounding areas, apart from the dry environment characterized by high temperatures, low humidity, and minimal precipitation (Sissakian et al., 2013).

The 60-year climate data, since 1960, are analyzed to understand the increased sand and dust storms in the Middle East. The area between the Tigris and Euphrates rivers, Syria, Saudi Arabia, and Jordan has been identified as a source of dust and is classified as anthropogenic or hydrological through satellite images (Awadh, 2023; Al-Dabbas et al., 2012). Mohammed and Alomari (2012) identified the most probable source of rising and suspended dust in Iraq as located in the Al-Jazeera region surrounding Al-Tharthar Lake from satellite images (Aqua and Terra) during 1970–2005. Cao et al. (2015) identified three clusters in the Tigris-Euphrates Plain as severe sand and dust storm sources in the West Asia region (2000–2013). Kadhum and Rasheed (2018) identified the sources and features of dust storms in Iraq, which were primarily located in the alluvial Tigris-Euphrates plain and extending northwestward into the Al-Jazeera area, with some sources close to the Iraqi-Iranian border. Boloorani et al. (2023) identified hotspot dust sources in the Tigris and Euphrates basins in the 2000–2021 period using visual analysis of satellite images. One of the dust sources that affect the Arabian Peninsula explored by Al-Hemoud et al. (2022) is the Mesopotamian floodplain in southern Iraq using MODIS Aqua and Terra satellites combined with the HYSPLIT model and synoptic meteorology during 2010–2018. Boloorani et al. (2021) found that the dried beds of water bodies are the primary source of dust emissions in the Tigris and Euphrates basins. Al-Hemoud et al. (2020) assessed thick dust trajectories from two "hotspot" areas (Mamlahat Al-Samawah and Al-Batha) of 4550 km^2 located 250 km from Kuwait's northern border in the middle of the Euphrates region of southern Iraq during 2007–2018. These dust storms spread not only to Kuwait but also to Saudi Arabia, Bahrain, and Qatar.

The study of dust storms is essential for understanding the principles of dust formation and analyzing its socioeconomic and environmental consequences. Identifying the origins helps in observing and predicting the path of dust storms and contributes to mitigating their harmful effects and enhancing control of this phenomenon (Cao et al., 2015). For example, if a source of dust storms is identified, measures can be taken to control or stabilize the exposed soil. Identifying these sources also aids in developing regional collaborations and agreements to effectively address the transboundary dust storm issues (Middleton, 2019).

A mixture of natural and human factors commonly causes dust storms in the Middle East. The area's particular geographic features, climate patterns, and human activities contribute to the formation and escalation of dust storms (Awadh, 2023). The Middle East consists of substantial wilderness areas, including the Arabian Desert, the Syrian Desert, and the deserts of Iran. These arid and semi-arid landscapes are characterized by massive expanses of fine particles, which can easily be picked up by wind and initiate the formation of a dust plume. Dust plumes can travel long distances, affecting not only the source location but also neighboring regions and distant areas (Al Ameri et al., 2019). Several meteorological factors contribute to the formation of dust storms in the Middle East. These include low-pressure systems in regions such as the Arabian Peninsula's thermal low and the Persian Gulf's monsoon trough. These systems create strong pressure gradients, resulting in increased wind speeds. The location often reports atmospheric instability due to different air masses, including cold fronts, hot air masses, and thunderstorm downdrafts. These situations can generate strong winds carrying dust debris over long distances (Ghazal, 2017).

The primary objective of this work is to identify the most frequent sources of dust storms in Iraq that occurred during 2020–2023 and to identify new sources of dust storms, using remotely sensed data to monitor their evolving trend over a given period to obtain a potential dust sources map. This map can help prioritize areas for action by responsible authorities to reduce dust storms. In this work, combined satellite images were extracted to monitor and detect the internal and external sources of the dust storms that occurred over Iraq, and their paths and frequencies were tracked using archive data from the meteorological satellite Meteosat-9 SEVIRI bands. Dust storm forward trajectories were simulated by the HYSPLIT model for the most frequent dust storm sources in the study area and for the selected period to determine the places affected by these dust storms and the direction of

Table 1
Dust RGB composition (Reinhardt et al., 2014),

Color	Channel (μ)	Physically relates to	Smaller contribution to the signal of	Larger contribution to the signal of
Red	IR12.0-IR10.8	Cloud optical thickness	Thin ice clouds	Dust
		Thin dust		Thick clouds
Green	IR10.8-IR8.7	Cloud phase	Thin ice clouds	Water clouds
			Dust	Deserts
Blue	IR10.8	Temperature	Cold clouds	Warm surface
			Cold surface	Warm clouds

their movement.

2. Study area

Iraq encompasses an area of approximately 438,314 km^2, situated between latitudes 29.05° N and 37.22° N and longitudes 38.45° E and 48.45° E (Fig. 1). The climate of Iraq is predominantly continental and subtropical, with the exception of the northern and northeastern mountainous regions (Al-Ansari, 2021). The average annual rainfall is about 213 mm, which is roughly one-third or less of the global average of 990 mm (Abdullah et al., 2020). The region's unique geography, coupled with human activities, significantly influences the frequency of dust storms. The high plateaus of Saudi Arabia, along with the towering mountains of Iran and Turkey, create a natural funnel for large air masses, allowing air to flow from the Mediterranean region into the Gulf and traversing Iraq (Soleimani et al., 2020).

Furthermore, upstream reservoirs have drastically diminished water levels in various Iraqi wetlands, exacerbating the situation. The prolonged drought and extreme weather patterns impacting West Asia have rendered Iraq particularly vulnerable to climate change-related phenomena, notably dust storms (Reed and Stringer, 2016). The dust storms occurring in Iraq from 2020 to 2023 have been meticulously studied and monitored. Their backward trajectories and sources have been identified, and a thematic map has been employed to delineate both the sources of dust storms and the most frequent contributors.

3. Data and methodology

3.1. Data

This study's dataset is obtained from the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), which provides extensive information about climate from earth observation, environment, and weather (Martinez et al., 2009). It operates the Meteosat 9, 10, and 11 satellites, currently positioned over Europe, Africa, and the Indian Ocean. These satellites are part of the Meteosat Second Generation (MSG) series in geostationary orbit at an altitude of 36,000 km above the equator (Guo et al., 2019). The main instrument on MSG satellites is the spinning enhanced visible and infrared imager (SEVIRI) (Schmid, 2000). SEVIRI scans the entire Earth disk and includes 12 channels, four of which have visible wavelengths and near-infrared rays, scanning the Earth with a sampling accuracy of 1 km.

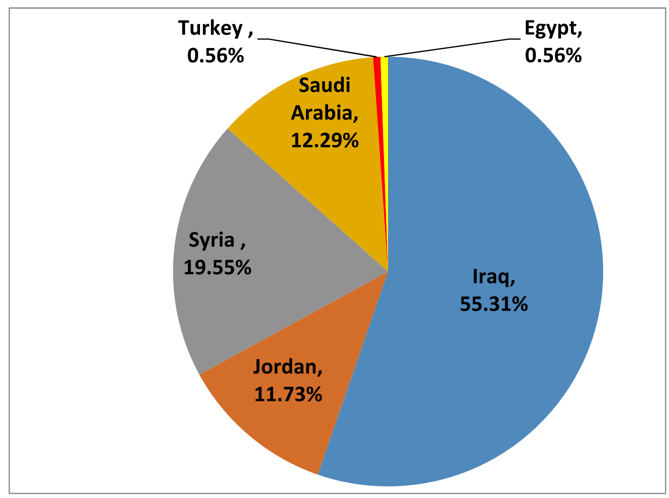

Fig. 3. Dust storm frequent percentage distribution for each country that occurred over Iraq during 2020–2023.

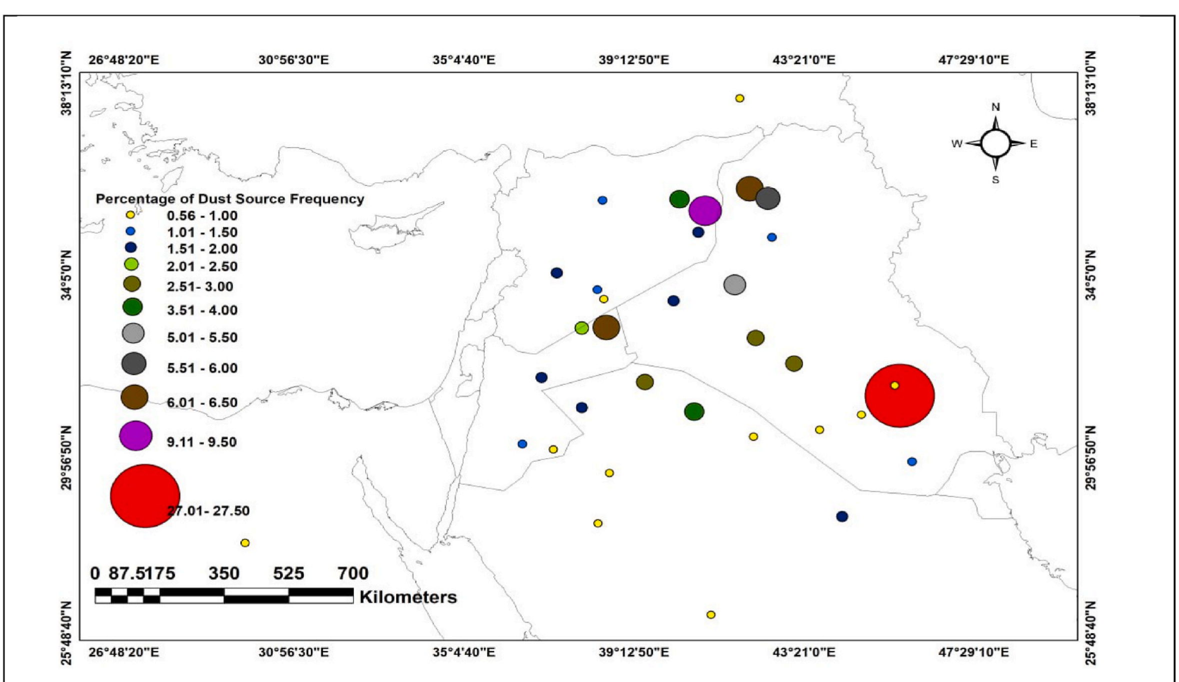

Fig. 2. Frequency percent map of dust storm sources over Iraq during 2020–2023.

Table 2
Seasonal dust storm frequency and its yearly percentage.

Season	2020		2021		2022		2023	
	No.	%	No.	%	No.	%	No.	%
Winter	0	0%	4	10.81%	3	6.98%	2	4.88%
Spring	1	9.09%	9	24.32%	23	53.49%	10	24.39%
Summer	7	63.64%	18	48.65%	17	39.53%	25	60.98%
Autumn	3	27.27%	6	16.22%	0	0%	4	9.76%

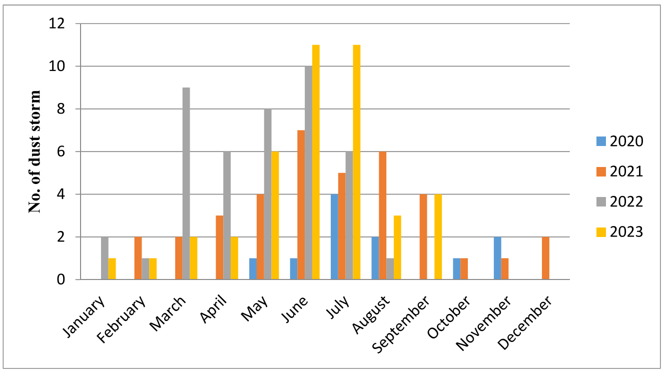

Fig. 4. Monthly frequency of dust storms that occurred over Iraq during 2020–2023.

It is an essential instrument for dust aerosol monitoring. It provides many meteorological and dust observations with high resolution in 15-min intervals, making MSG satellites a powerful and unique tool for delivering various observations, especially of rapidly and continuously changing meteorological components (Schmid, 2000). The dust RGB image (Red, Green, and Blue) bands, along with true natural colors and thermal infrared channels, form the basis for the SEVIRI dust recovery tool. The RGB SEVIRI composite images show magenta dust aerosols with 3 km spatial resolution and are distinctive and unique (Banks et al., 2019); this study uses Meteosat–SEVIRI images to identify dust storm sources.

3.2. Methodology

Dust RGB SEVIRI images offer good temporal resolution and color contrast, though they do not provide information on height and concentration. Their movement can be traced back to the source of the dust, as they operate over deserts. SEVIRI's 15-min loop photos can identify minor dust puffs and slight variations from one image to another (Hennen et al., 2019). EUMETSAT recommends using RGB composite images for dust monitoring. The Dust RGB composition is derived using infrared channel data obtained from SEVIRI. It is intended to track the development of dust storms occurring in deserts during both day and night, where dusty pixels appear magenta (Martinez et al., 2009). To create the Dust RGB composite images from the Meteosat 9–SEVIRI bands, the subtraction between the thermal bands (IR12.0–IR10.8) is used for the red channel, and the subtraction between the thermal bands (IR10.8–IR8.7) is used for the green channel, resulting in dust being displayed in magenta color (Reinhardt et al., 2014), (Table 1).

They determined the sources of dust storms in Iraq through a subjective analysis of time series data obtained from the SEVIRI 'Dust RGB' dataset. The identification of dust emission sources is conducted through visual observation of various indicators, such as the presence of dust plumes, variations in surface reflectance, alterations in color and texture, and a solid understanding of the study area. By analyzing these characteristics in RGB imagery and tracing the initial indications of dust backward through a series of images, potential regions where dust originates can be identified. These locations were considered the source of the dust. Every dust emission event is documented as a point source location with the corresponding time and date of initial appearance in the SEVIRI images. Full SEVIRI 'Dust RGB' images, each 15 min apart, were obtained for 132 dust storms that occurred in Iraq during the four years from 2020 to 2023. Data on dust storm events, including the date, start time, end time, location of each source, and source frequency, were collected and sorted into a shapefile to create thematic maps of dust storm sources by determining the geographical coordinates of dust export sites. The geographical coordinates of the major countries were used as a reference for digitizing maps using the WGS84 coordinate system and the ArcGIS 10.3 program. A degree of confidence is assigned to the SEVIRI 'Dust RGB' dataset, which is manually validated by comparing it with data from the Iraqi Meteorological Organization and Seismology. This data included information on Iraqi dust storms every 60 min for the years 2020–2023 from 10 weather stations distributed throughout Iraq, including visibility, wind speed, air temperature, and relative humidity.

The Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model uses geographically and temporally gridded meteorological data to simulate the movement of wind parcels resulting from wind advection. It is one of the most widely used models for the distribution and transport of atmospheric pollutants in large-scale research, which was created and developed by the United States National Oceanic and Atmospheric Administration (Rolph et al., 2017). The HYSPLIT model is used to determine the forward trajectories for the most frequent dust storm sources and to follow the paths of dust storms that occurred in the Middle East during the selected period. Forward trajectories are obtained by running HYSPLIT using the regular trajectories option based on data from the Global Forecast System (GFS) at a 0.25-degree resolution. The geographic coordinates of the source point and starting altitude are required inputs for the HYSPLIT forward trajectory online model, which produces GIS shapefile trajectories made up of discrete points with coordinates, time, and height as outputs, with a resolution of 96 dots per inch (dpi).

4. Results and discussion

In this work, 132 documented dust events occurred or passed through Iraq. These generally originated from Iraq, Syria, Saudi Arabia, Jordan, Egypt, and Turkey, extending in various directions, including Kuwait, Saudi Arabia, the Arabian Gulf, and Iran. Data analysis found that most dust storms are generated during daylight hours, with 95.53% of all dust events occurring during the study period, while 4.47% were generated at night. Geographic information systems (ArcGIS) software is used to create a thematic map to identify dust storm sources and the frequency of each source that occurred over Iraq during 2020–2023 (Fig. 2).

Fig. 2 illustrates Iraq's most frequent dust storms during 2020–2023. The dust storms in Iraq can be grouped into 12 sources, forming 99 dust events. Years of drought and desertification result from the inappropriate management of water resources, farming activities, climate change, and incessant wind erosion. These have led to soil degradation, contributing to an increase in dust storm sources. The most frequent dust storm sources were in southern Iraq, accounting for 27.37%. This source is located at (45°40′ E, 31°22′ N) in the province of Al Muthanna, marked in red.

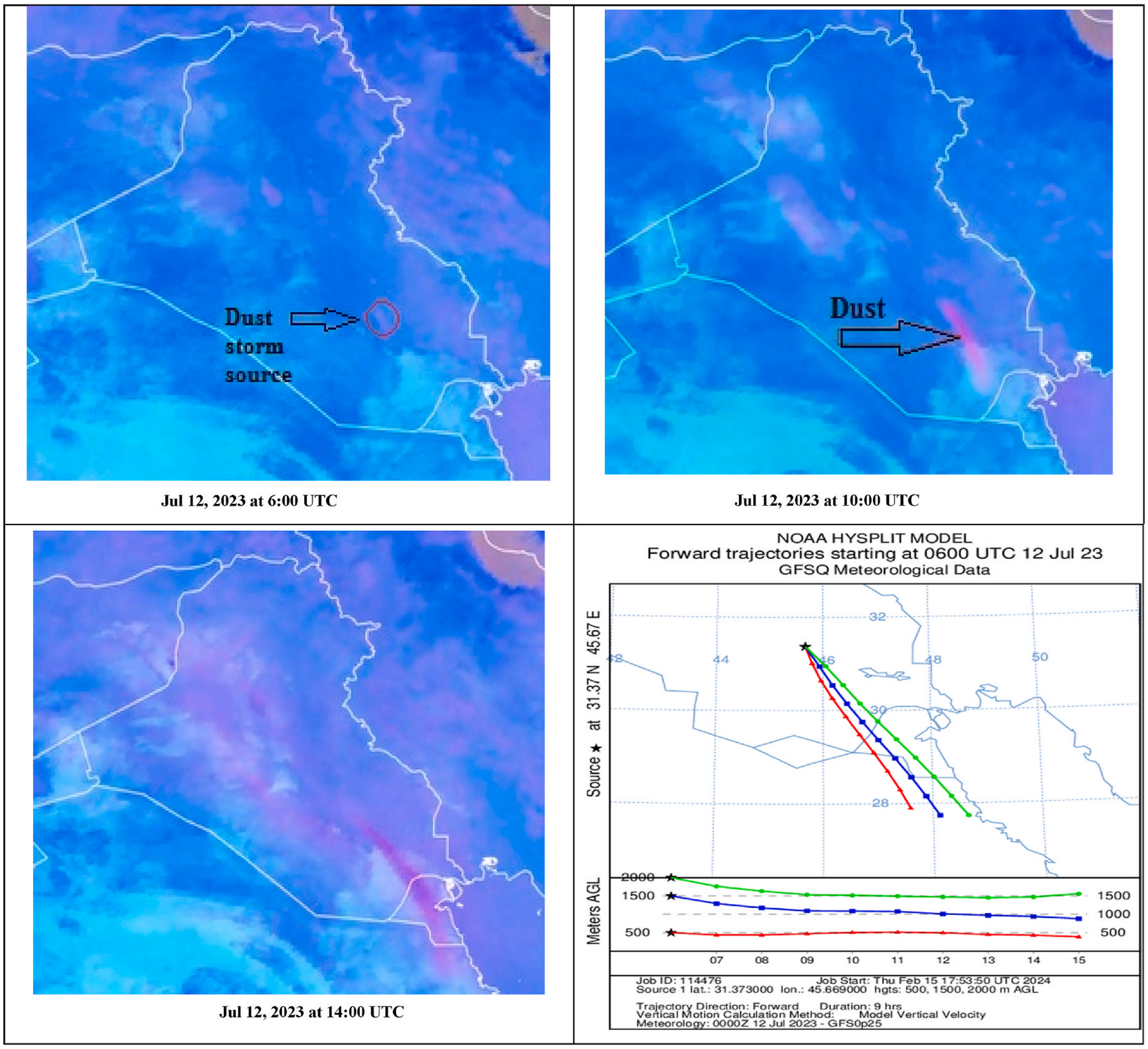

Fig. 5. RGB images from EUMETSAT for dust storms evolution and their HYSPIT forward trajectories simulations on Jul 12, 2023.

In Syria, the Mediterranean climate influences the northern and coastal regions, while the environment in the southern areas is considered a tropical desert. Syrian dust sources can be grouped into six sources, forming 35 dust events over Iraq. The most frequent dust sources in Syria are in the eastern part, accounting for 9.50%, located at (40°56′ E, 35°29′ N) in the Deir Ez-Zor District, marked in purple.

Jordan has five dust sources, which have caused 21 dust events in Iraq. The dominant wind from the Mediterranean governs all dust storm sources. High-frequency dust sources are in the eastern part, northeast of the Governorate of Mafraq (Al-Rwaished District), accounting for 6.15%, located at (38°31′ E, 32°54′ N), marked in brown.

The sources of dust storms in Saudi Arabia can be grouped into nine sources, which have formed 22 dust events. The Arabian Desert dominates Saudi Arabia, with a depression originating north of Africa, while the southeast Mediterranean Sea influences the central and southern regions. The high frequency of dust sources is found in the northern border area, accounting for 3.91%, located at (40°40′ E, 31°00′ N), marked in green. Egypt and Turkey do not have sources that significantly affect the generation of dust storms in Iraq; only one source is recorded from 2020 to 2023.

The results are consistent with identified sources from previous research studies conducted between 1960 and 2021, which identified the area between the Tigris and Euphrates rivers, Syria, Saudi Arabia, and Jordan as dust sources. Additionally, new dust sources have been identified in Iraq's southwestern and western regions, such as the Al-Nukhaib area, Wadi Hauran, and Sinjar, along with new sources in Syria, Jordan, and Saudi Arabia. Mohammed and Alomari (2012) identified the most probable source of rising and suspended dust in Iraq as located in the Aljazeera region surrounding Al-Tharthar Lake from satellite images (Aqua and Terra) during 1970–2005. While conducting this study, a region in the Samawah Desert, north of the Dhi Qar governorate, is identified as the most frequent dust storm source from 2020 to 2023.

The findings are consistent with the information and measurements from the Iraqi Meteorological Organization and Seismology and the weather reports from the Syrian General Directorate of Meteorology and the Jordan Meteorological Department to ensure results accuracy. The results in identifying the dust sources are consistent based on the specified dates and times.

To assess the frequency of dust storm sources that occurred over Iraq, coming from different countries, a probability percentage (P%) is evaluated. The probability is the number of frequent dust sources in each country divided by the total number of all sources over a specified period, January 2020 to December 2023, as in the following equation (Halos, 2017):

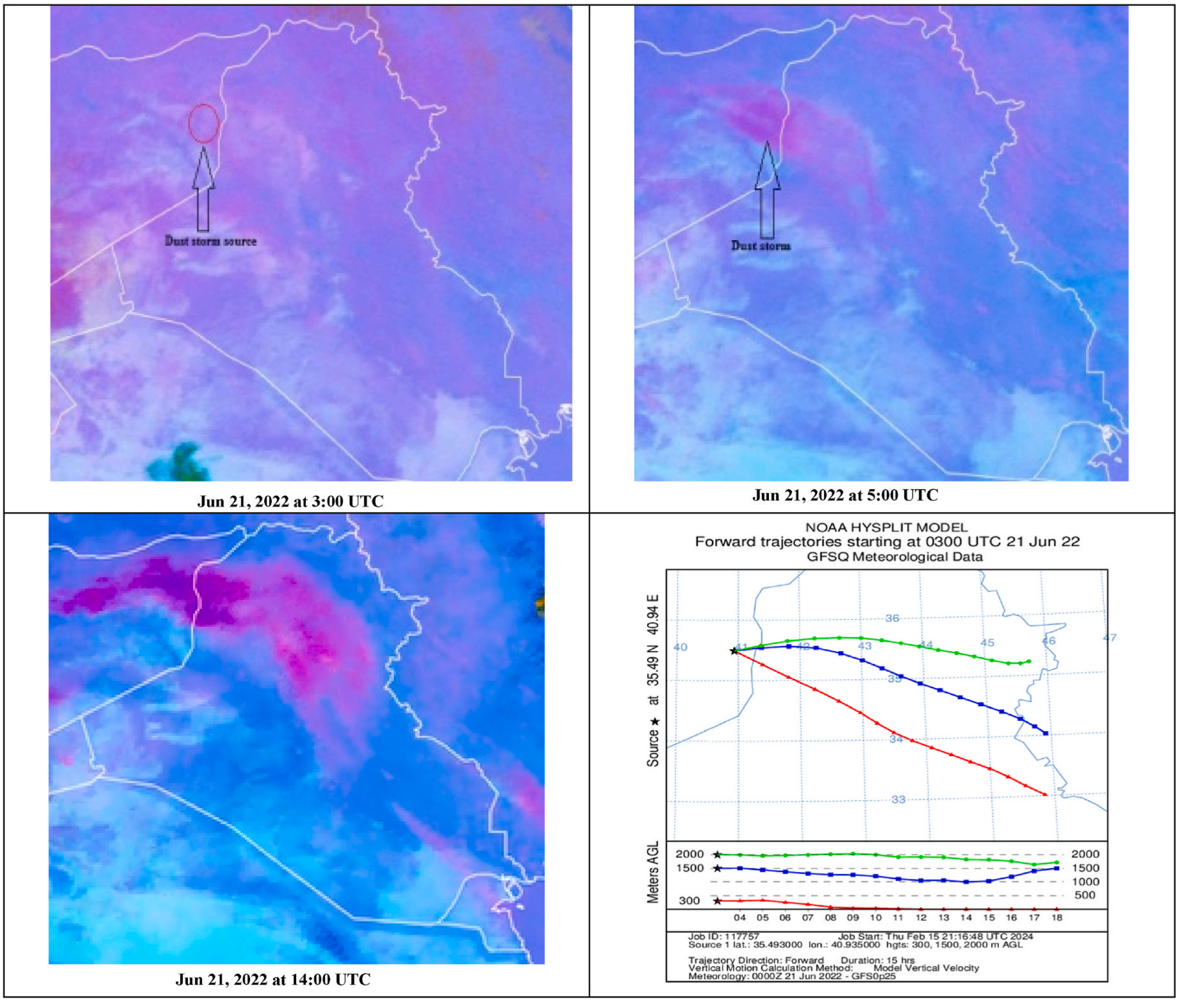

Fig. 6. RGB images from EUMETSAT for dust storms evolution and their HYSPIT forward trajectories simulations on June 21, 2022.

$$P\% = \frac{\text{The number of dust sources frequent in each country}}{\text{Total number of all sources frequent}} \times 100\ \% \tag{1}$$

The probability percentage of dust storm sources between Iraq and other countries is shown in Fig. 3., which indicates that local sources account for the highest rate of the total sources. There were 179 dust events, of which 132 were emitted from local sources, resulting in a local sources percentage of 55.31%, while the regional sources percentage is 44.69%. These regional sources are distributed among Iraq's neighboring countries: Syria at 19.55%, Saudi Arabia at 12.29%, Jordan at 11.73%, Turkey at 0.56%, and Egypt at 0.56%.

Dust storms are more common in the spring and summer, accounting for approximately 72%–93% of annual dust storms (Table 2). This prevalence is due to the weather conditions in spring, which are more favorable for dust storm formation, characterized by reduced precipitation, increased wind speed, higher average temperatures, and summer droughts that enhance the likelihood of re-suspension (Al-Khalidi et al., 2021). The monthly dust storm frequency distribution is displayed in Fig. 4. The results indicate that dust storms are more common in May, June, and July over the four years, as well as in March 2022.

5. HYSPLIT trajectory simulation

The HYSPLIT model is used to determine the forward trajectories for sources of more frequent dust storms for countries (Iraq, Syria, Jordan, and Saudi Arabia) to determine the places that are effected by these dust storms and the direction of its movement to determine the potential impact and magnitude of damage caused by those storms. The evolution of dust storms in Iraq using Dust-RGB images from EUMETSAT and HYSPIT forward trajectories are shown in Figs. 5–8.

The forward trajectories are calculated by integrating the airflow over time using three-dimensional wind data to determine the regions affected by these dust storm sources. Fig. 5 illustrates the trajectory starting from Iraq (45°40′E, 31°22′N) at 6:00 UTC on July 12, 2023, with a duration of 9 h at altitudes of 500, 1500, and 2000 m above ground level (AGL).

Fig. 6 illustrate the trajectory's start from Syria (40°56′ E, 35°29′ N), at 3:00 UTC on June 21, 2022 with the duration of each track 15 h of 300, 1500, and 2000 m AGL. The prevailing wind direction is from the northwest. This is known as the Shamal wind, a hot and dry northwesterly wind blowing across the region. The Shamal wind can bring dusty conditions and affect visibility. The dust storm source in Iraq impacts on the governorates of southern Iraq (Dhi Qar and Basra), Kuwait, and northeast parts of Saudi Arabia.

In contrast the dust storm source in Syria has a significant impact on the northwest and the northern parts of Iraq in addition to the Tigris and Euphrates basin encompassing, and it may extend to both Kuwait and Iran.

Fig. 7 illustrates the trajectory starting from Jordan (38°31′ E, 32°54′ N) at 8:00 UTC on March 29, 2023, with a duration of 13 h at altitudes of 300, 1500, and 2000 m AGL. The prevailing wind direction is often from the west, influenced by westerly winds that blow from west to east in the spring. However, the strength and consistency of these westerlies can

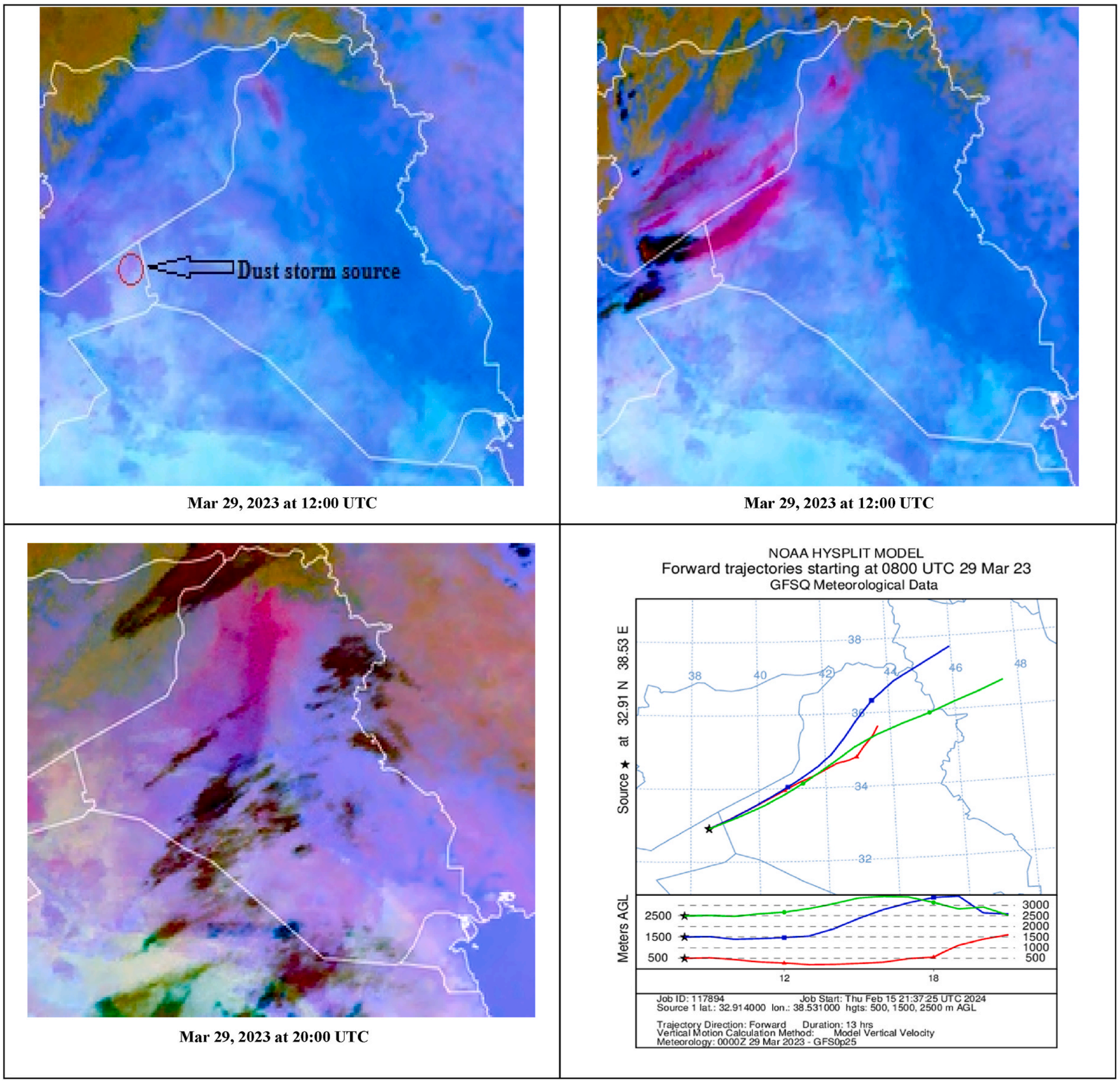

Fig. 7. RGB images from EUMETSAT for dust storms evolution and their HYSPIT forward trajectories simulations on Mars 29, 2023.

vary. Mountain ranges can cause channeling and deflection of winds, leading to localized wind direction and speed variations. Dust from this source is frequently blown into Iraq and may extend to Iran.

Finally, the dust storm source in Saudi Arabia (40°40′ E, 31°00′ N) was observed at 5:00 UTC on February 18, 2021, with a duration of 20 h at altitudes of 300, 1500, and 2500 m AGL. The prevailing winds in this region also blow from west to east, as shown in Fig. 8. Dust from this source is commonly transported to Iraq, and its characteristics align with those of sources in northeastern Jordan; it may also extend to Iran or Kuwait due to the influence of the Shamal wind.

The EUMETSAT observations were consistent with the HYSPLIT simulation and the information and measurements of the Iraqi Meteorological Organization and Seismology.

6. Conclusions

This study's results indicate that most dust storms occur during the day, with 95.53% of all dust events recorded during the study period, while only 4.47% occur at night. This research found that utilizing SEVIRI data with its 15-min cycle, the Meteosat satellite is essential in determining the source locations and trajectories of dust storms in Iraq. The dust mask generated by SEVIRI and HYSPLIT model trajectories effectively identified the source regions of dust storms and their transport pathways. The thematic map illustrating potential dust storm sources aligns with the current situation and existing literature while identifying new dust storm sources.

Regarding temporal distribution, 132 dust storms occurred in the Middle East over the four years, in 2022. This year has the highest frequency, but 2020 has the least frequent. These findings are consistent with previously identified sources in the literature. Additionally, new dust sources have been identified in the southwestern and western regions including the Al-Nukhaib area, Wadi Hauran, and Sinjar, as well as new sources in Saudi Arabia, Jordan, and Syria. The Most frequent storm source locations are concentrated in Iraq, accounting for 55.31%, primarily situated within the western desert and Aljazeera region. Syria follows this at 19.55%, Saudi Arabia at 12.29%, and Jordan at 11.73%. The highest frequency of dust storm sources in Iraq is in the southern region of the Al-Samawa desert, representing 27.37% of all dust sources in Iraq. Dust storm activities tend to increase during the spring and summer months, particularly from March to September, due to the influence of atmospheric systems, rising temperatures, and a lack of rainfall, contributing to soil fragility. In contrast, dust storm activities decrease during autumn and winter.

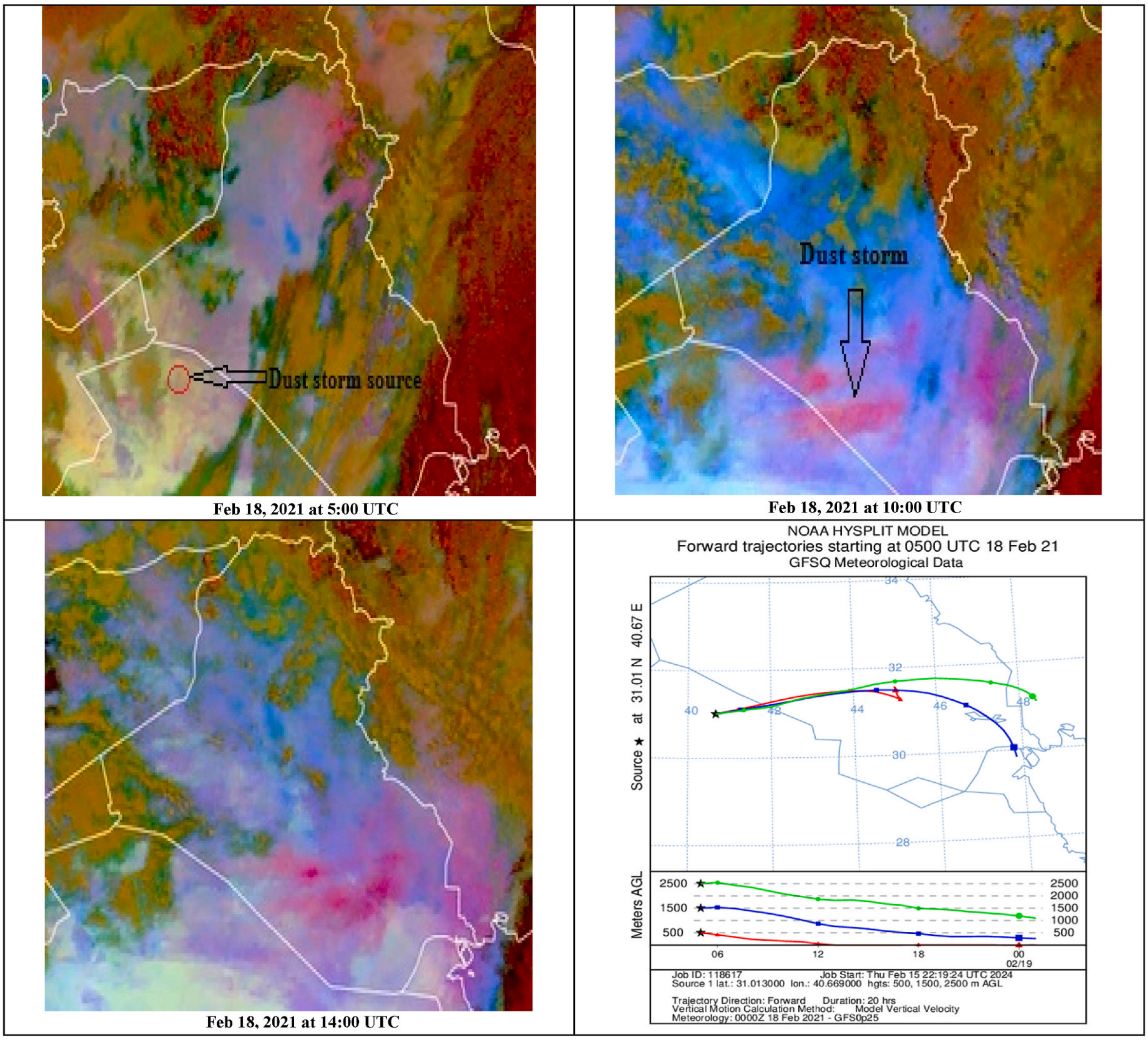

Fig. 8. RGB images from EUMETSAT for dust storms evolution and their HYSPIT forward trajectories simulations on February 18, 2021.

CRediT authorship contribution statement

Rafah R. Ismail: Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation. **Saadiyah H. Halos:** Supervision, Methodology. **Bushra Q. Al-Abudi:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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