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Severe Meteorological Factors Affecting Civil Aviation Flights at Iraqi Airports

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ABSTRACT

By studying the impact of severe weather conditions on civil aviation flights at Iraqi international airports, data were obtained from the General Authority for Meteorology and Seismic Monitoring, the Iraqi Civil Aviation Authority and Iraqi Airways, as daily data for Baghdad International Airport, Erbil Airport, Sulaymaniyah Airport, Najaf Airport and Basra Airport.
The frequency of occurrence of thunderstorms, dust storms, fog and snow were calculated and analyzed depending on the extent of horizontal visibility to determine the hours of air closure and aircraft movement at all airports of the study.
This paper also discussed the temperature and its effect on the take-off and landing processes, the results showed that Baghdad International Airport was greatly affected by the occurrence of fog, followed by the airports of Erbil and Sulaymaniyah and their impact by the occurrence of thunderstorms and snow, while both Najaf Airport and Basra International Airport were greatly affected by dust storms.

KEYWORDS: Civil Aviation; Flight; Fog; Thunderstorm; Dust storm; weather; Cross wind; Iraq.

الخلاصة

من خلال دراسة تأثير الظروف الجوية القاسية على رحلات الطيران المدني في المطارات العراقية الدولية، تم الحصول على البيانات من الهيئة العامة للأرصاد الجوية والرصد الزلزالي وهيئة الطيران المدني العراقية والخطوط الجوية العراقية، كبيانات يومية لمطار بغداد الدولي ومطار أربيل، مطار السليمانية ومطار النجف ومطار البصرة. تم حساب وتحليل وتيرة حدوث العواصف الرعدية والعواصف الترابية والضباب والثلوج اعتمادًا على مدى الرؤية الأفقية لتحديد ساعات الإغلاق الجوي وحركة الطائرات في جميع مطارات الدراسة. اظهرت النتائج تأثر مطار بغداد الدولي بشكل كبير بحدوث الضباب يليه مطاري اربيل وسليمانية وتأثيرهما بحدوث العواصف الرعدية والثلوج فيما تأثر كل من مطار النجف ومطار البصرة الدولي بشكل كبير بهبوب العواصف الترابية.

INTRODUCTION

Weather is the most significant factor affecting aircraft operations, accounting for 70%–80% of passenger delays [1]. Among the severe weather factors affecting aviation are thunderstorms, fog, dust and snow storms, high temperatures, and winds. Thunderstorms are one of the most dangerous weather factors for aviation as they can produce large hail, damaging winds and less frequent hurricanes. Thunderstorms usually consist of several independent convective systems or "cells" [2]. Thunderstorms can produce and develop in any geographical location, but they are often in the mid-latitudes when warm, moist air from the equatorial region collides with cold air from the polar region and rises upward in the rapid movement to cooler layers in the atmosphere, and condensation of moist air occurs and as a result, Instability occurs and towering cumulus clouds are formed that reach the height of the tropopause layer. Prediction and detection of thunderstorm locations are via satellites and weather radar, where specialists monitor the clouds that are forming rapidly, which are evidence of the possibility of a thunderstorm and the temperature of its tops, which is very low for its high altitude [3]. Fog, which is a natural phenomenon that is low clouds close to the surface of the earth, affects the movement of flights. Fog conditions often reduce aircraft arrival, departure flow rates and can become dense enough to close an airfield. Fog is the most common visibility limiter in aviation. When fog is anticipated crews will need to consider airport

alternates, and carry additional fuel due to the conditions generated by fog. Fog has the potential to rapidly reduce visibility, from visual flight rules (VFR) to instrument flight rules (IFR) within minutes [4]. Fog conditions can change abruptly within an airport, making them transitory. Fog evolves geographically, which makes it challenging to forecast and predictably disperse fog density [5]. Ice is formed when the temperature drops to zero degrees Celsius with high humidity in the atmosphere, Snow is considered one of the dangers that threaten air transport, as the ice that forms aircraft causes delays in flight times, in addition to causing the aircraft to increase in weight, which leads to reduced efficiency and difficulty in the take-off process. The ice also causes disruption of engines, radio and navigational devices [6]. Dust storms pose a serious risk to aviation. They significantly reduce visibility and are accompanied by very high gusts, which can seriously impact an aircraft in flight. Ingesting dust can cause catastrophic harm to motors [7]. The performance of an aircraft during takeoff and landing is significantly impacted by temperature. A plane's engine performance is not the only thing that may change; flight aerodynamics can also change [8]. When temperatures rise, the air density decreases, and as a result, the efficiency of the aircraft's engines decrease and the lifting force required to lift the aircraft decreases, which leads to the need for longer runways or a reduction in the weight of the aircraft. As for the upper layers of the atmosphere, 39,000 feet, which is the best level for flying, the temperature is approximately -55 ^{0}C, and at this temperature, the efficiency of the aircraft's engines is highest [1]. Accidents caused by bad weather accounted for about 10% of the total accidents, and most of the aviation accidents that occurred during the take-off and landing process were due to crosswinds. In cross-wind conditions, the perfect final landing process begins elaborately with the aircraft positioned on the glide path as well as aligning the aircraft's speed on the runway with its center line before the aircraft tires touch the runway and begins to glow [9]. There are three landing techniques used by airlines that require continuous winds (no gusts) which are De-crab, crab, and sideslip where wind data is taken for a 45-meter-wide runway and from a 10-meter-high tower, these techniques are used for landing on the event of crosswind on the runway [10]. The majority of the United States' winter weather (snow, sleet, freezing rain, strong winds, low clouds, and low visibility) was studied by Ballesteros *et al.* (2018) [11], the study showed that snowstorms were the biggest cause of aircraft cancellations. Thobois *et al.* (2019) [12] studied the meteorological processes such as wind shear, wind profiles, gust fronts, and wake vortices over airports, and suggested that the use of Doppler lidars can significantly improve the safety of flight environments along landing and takeoff at airports by giving caution to pilots and ground crew and optimizing air-traffic management. Nechaj *et al*. (2019) [13] used ground-based 3D Lidar monitoring of low-level wind shear to evaluate the weather events recorded throughout a year with respect to the occurrences of low-level wind shear for increasing the flight safety. Peck and Hedding (2017) [14] studied thoroughly assessing adverse weather risks by developing a weather impact index depending on a study of all departure delays due to adverse weather over the airport in South Africa for the period 2010–2013.

The purpose of this work is to study the effect of extreme weather factors on the postponement or cancellation of flights at Iraqi airports.

This research included an introduction in the first section, Data source and study stations in the second section, the third section includes the Methodology, and the fourth section implicates the results and discussion and the final section includes the conclusions.

DATA SOURCE AND STUDY STATIONS

Daily data (civil aviation flights, temperature, wind speed and direction, and atmospheric pressure from the surface of the earth up to 40,000 feet) for the period (2019-2020) for Iraqi international airports monitoring stations (Baghdad Airport, Erbil Airport, Sulaymaniyah Airport, Najaf Airport, Basra Airport) as shown in Figure 1, with some information about each airport in Table 1. The data acquired from the Iraqi Civil, Aviation Authority [15], and from the Directorate of Transportation and Communications Statistics in the Iraqi Ministry of Planning [16]. Regarding the severe meteorological factors under investigation in this study, daily averages data acquired from the Iraqi Meteorological Organization and Seismology including (Fog, Thunderstorms, Snowfall and Dust torms) were used [17].

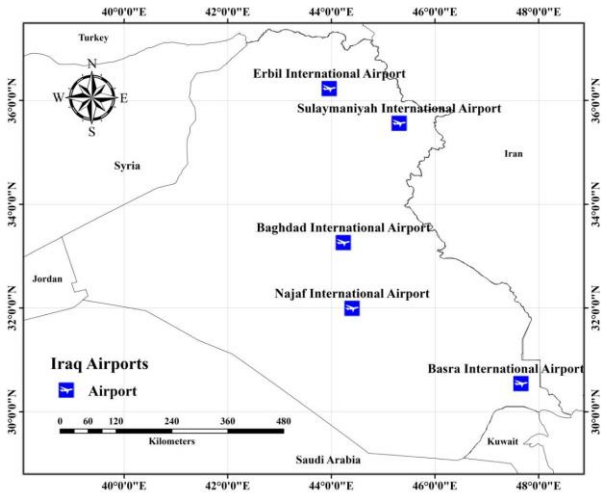


Figure 1. The studied locations of Iraqi international airports.

MATERIALS AND METHODS

Weather conditions are the main reason for closing the airspace to navigation. Data on weather conditions (thunderstorms, fog, snow, dust storms) were obtained from the General Authority for Meteorology and Seismic Monitoring, where each case and its impact on navigational movement were determined using the data of air transport statistics related to flights and their postponement, according to the instructions of the International Civil Aviation Organization Airports that fall within the CATII classification may close the airport's airspace when the horizontal visibility reaches a barrier of 800 meters or less, and since Iraqi airports fall under this classification, therefore, any weather condition that causes a deterioration in the range of horizontal visibility, it causes the closure of the airspace and the postponement of flights until The weather condition improved and the horizontal visibility reached 800 meters and more. The duration of closing the airspace to the movement of landing or take-off aircraft depends on the duration of the weather condition, whether it is fog, dust storm, or others [15].

Table 1. Iraqi airports details [15].

Iraqi rank	Airport name	ICAO code	IATA code	Latitude	Longitude	Height above sea level	Total passenger boarding	Runways
1	Baghdad International Airport	ORBI	BGW	33.263	44.235	114 ft	803,352	4000mx60m
2	Erbil International Airport	ORER	EBL	36.238	43.963	1341 ft	388,007	4800mx75m
3	Sulaymaniyah International Airport	ORSU	ISU	35.562	45.317	2494 ft	98,748	3499mx45m
4	Najaf International Airport	ORNI	NJF	31.99	44.404	103 ft	267,527	3000mx45m
5	Basra International Airport	ORMM	BSR	30.549	47.662	11 ft	142,957	4000mx45m

RESULTS AND DISCUSSION

Estimating the frequency of thunderstorms

Thunderstorms are classified as either a thunderstorm with precipitation (hail or rain) or without precipitation. Thunderstorms are also classified as light, moderate, and severe thunderstorms. Jet planes can only fly safely over thunderstorms if their flight altitude is much higher than the turbulent cloud tops [18]. The most severe and turbulent storms are often higher and larger (cumulonimbus clouds), so flights on the way always seek to go around them and rarely penetrate them as well as avoid passing between the cumulonimbus clouds due to the strong electrical charges that these clouds carry, and also avoid penetrating the clouds which are above the refrigeration because of its impact on the plane, perhaps the hail is of a large size, which causes serious damage to the plane, and may also cause damage to the devices and sensors on board [15]. There are 70 thunderstorms recorded at Baghdad International Airport, whether with or without precipitation, for 43 days during the study period, which included the months (Jan., Feb., Mar., Apr., May., Oct., Nov and Dec), where the horizontal visibility reached 2000 meters and a maximum wind speed of 15 m/s (30 knots) at the surface. See Figure 2.

During the study period, Erbil International Airport monitoring station recorded 60 thunderstorms, that were repeated in Jan., Mar., Apr., May., Jun., Aug., Oct. and Nov., while Apr. and Mar. have the most frequent occurrences of thunderstorms and the least in Feb., Jun., Aug. and Nov. See Figure 3.

The monitoring station of Sulaymaniyah International Airport recorded the occurrence of dozens of thunderstorms during the study period, where the station recorded more than 80 observations of strong and medium thunderstorms, which were concentrated in Apr. to the highest frequencies, while the lowest frequencies were in June and were not recorded in July, see Figure 4.

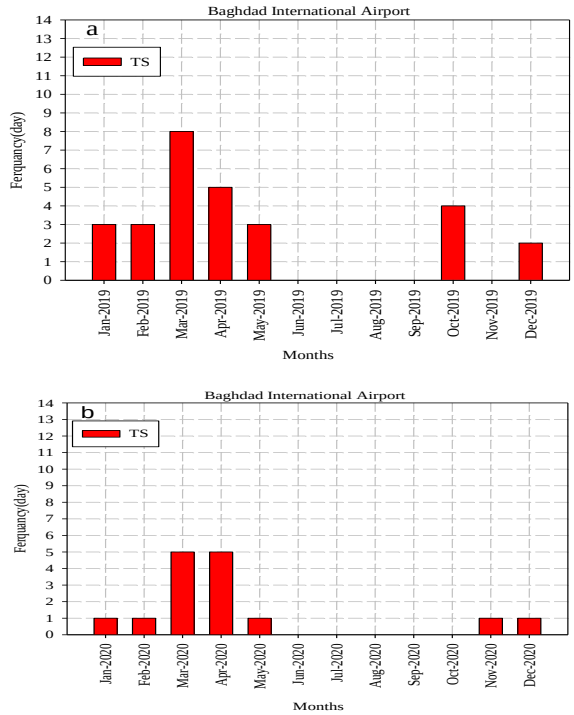


Figure 2. Thunderstorms (TS) at Baghdad International Airport monitoring station (a.2019) and (b.2020).

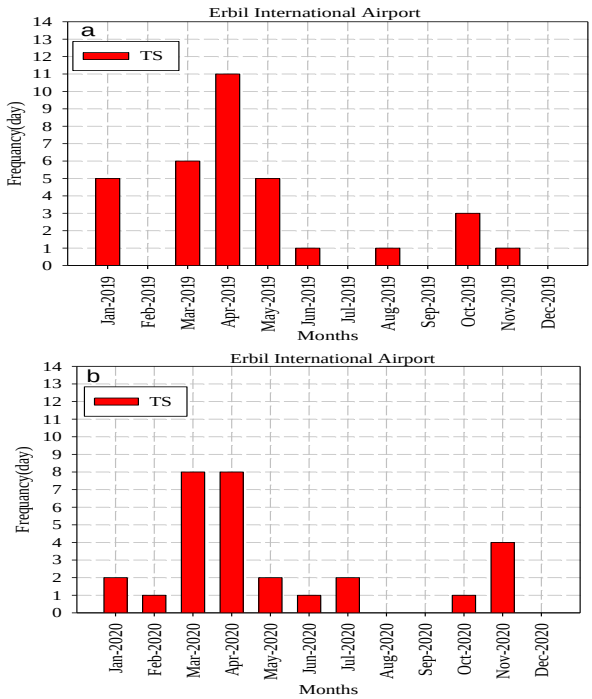


Figure 3. Thunderstorms (TS) at Erbil International Airport monitoring station (a.2019) and (b.2020).

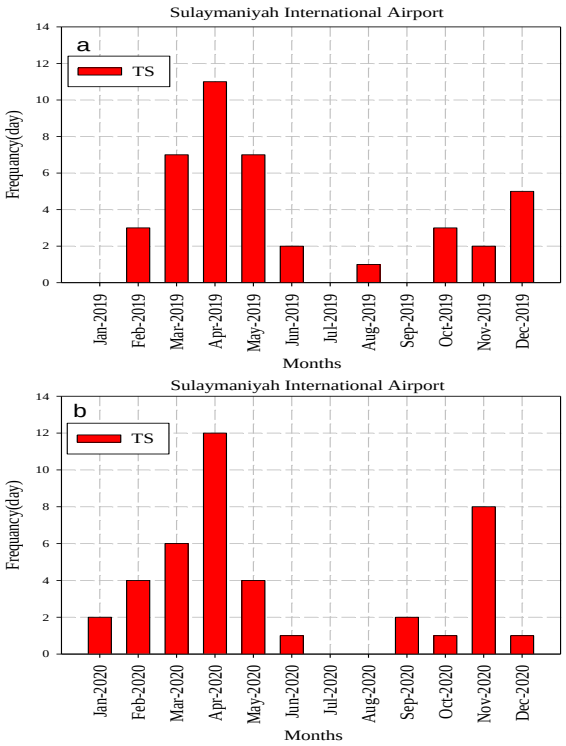


Figure 4. Thunderstorms (TS) at Sulaymaniyah International Airport monitoring station (a.2019) and (b.2020).

Basra International Airport monitoring station recorded the occurrence of dozens of thunderstorms during the study period. During a thunderstorm, the wind was 18 meters/sec (36 knots) at the surface and the minimum horizontal visibility range is 1000 meters. See Figure 5.

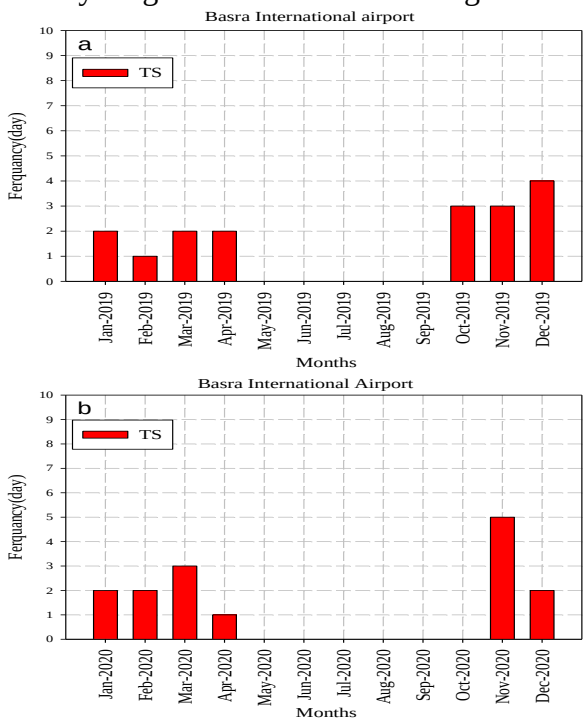


Figure 5. Thunderstorm at Basra International Airport monitoring station (a.2019) and (b.2020).

Najaf International Airport station monitoring recorded 20 thunderstorms spread over 13 days during the year 2020 only, concentrated in the months of Jan., Feb., Mar., Apr., Nov. and Dec. The highest occurrences of thunderstorms in March. Thunderstorms cause strong winds with precipitation accompanied by lightning and thunder, which requires closing the airspace if the storm is above the airport in order to preserve safety because of the damage it causes to aircraft, especially during take-off and landing. The data for 2019 it's not available. See Figure 6.

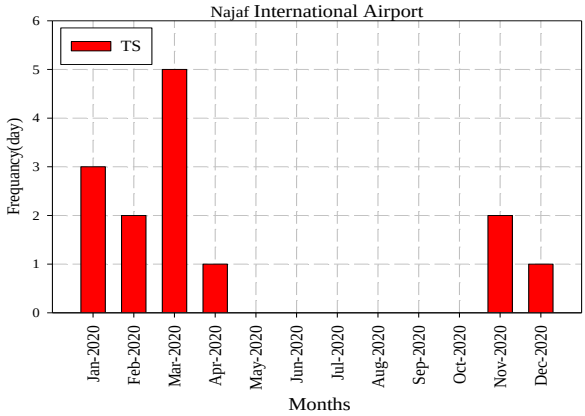


Figure 6. Thunderstorm at Najaf International Airport monitoring station for the year 2020.

Estimating the frequency of Fog

Atmospheric elements, including fog, affect the extent of horizontal vision, as the fog causes the extent of horizontal visibility to deteriorate to its lowest levels, as it can reach zero meters, the airspace of Iraqi international airports is closed when the horizontal visibility reaches 800 meters or less, (as we mention in the introduction part). During the study period, the fog caused 147 times closures of Baghdad Airport, spread over 30 days, according to the fog-formed time. These months are Jan., Feb., Mar., Apr., Nov. and Dec. Most of the fog cases occurred in Dec., and consequently, dozens of flights were postponed. See Figure 7.

Erbil International Airport monitoring station recorded 27 fog observations of fog during the year 2020, concentrated in the months of Jan. and Dec. which leads to closing the airport's skies and delaying departing and incoming flights to the airport. See Figure 8

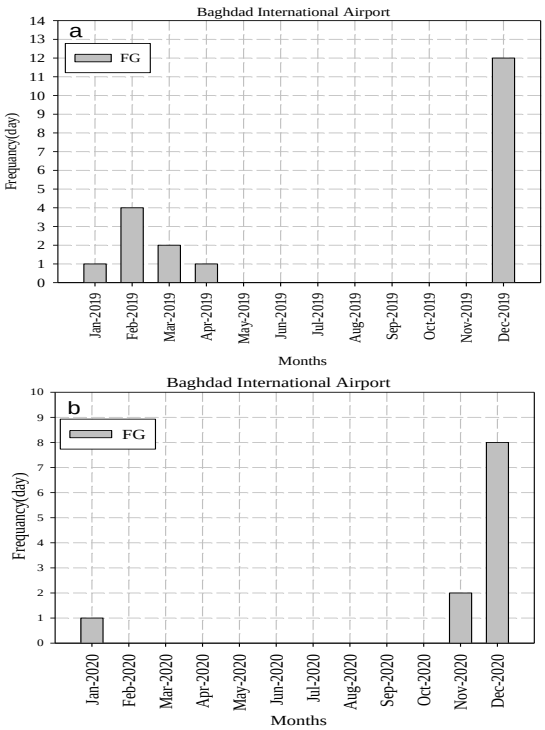


Figure 7. Fog (FG) at Baghdad International Airport monitoring station (a.2019) and (b.2020).

Figure 8. Fog (FG) at Erbil International Airport monitoring station for the year 2020.

The monitoring station of Sulaymaniyah International Airport recorded 22 fog observations during the year 2020, concentrated in the months of Mar., Nov. and Dec. See Figure 9.

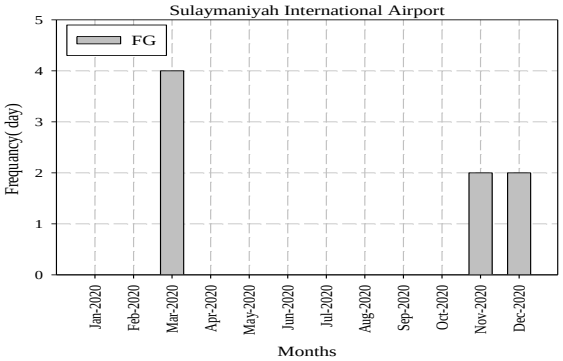


Figure 9. Fog (FG) at Sulaymaniyah International Airport monitoring station for the year 2020.

Najaf International Airport monitoring station recorded 23 fog observations during the study period. See Figure 10.

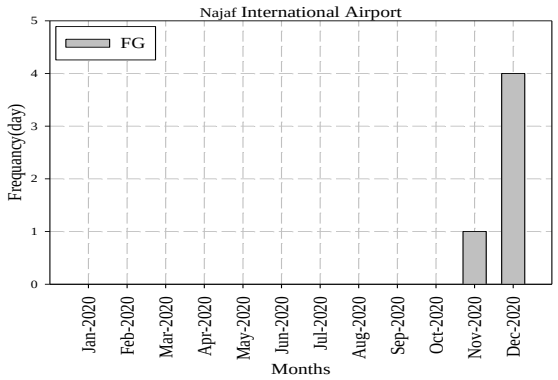


Figure 10. Fog (FG) at Al-Najaf International Airport monitoring station for the year 2020.

Finally, Basra International Airport monitoring station recorded 30 observations of the occurrence of fog (the horizontal visibility range is less than 1000 meters), intense Fog occurred on 11 days in Jan., Nov. and Dec. The lowest wind speed was recorded at 00 m/s, while the maximum wind speed was 4 m/s at the surface. The airport was closed due to fog during the study period for approximately 28 hours, then many flights were postponed. See Figure 11.

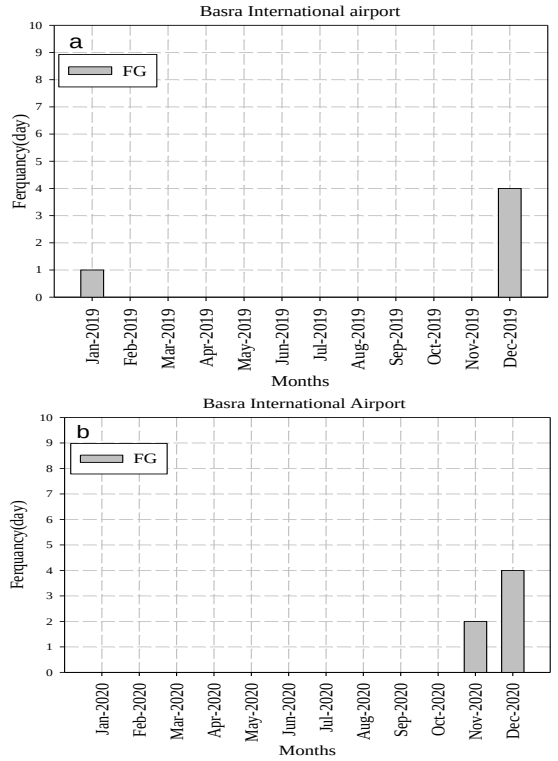


Figure 11. Fog (FG) at Basra International Airport monitoring station (a.2019) and (b.2020).

Estimating the Frequency of Snow

It hasn't snowed at Baghdad airport for several years, as snow rarely falls in the central and southern regions of Iraq, but during the year 2020, snow fell in February and lasted for about 3 hours, as the snow-covered trees and buildings, but the airspace was not closed in front of aircraft movement. See Figure 12.

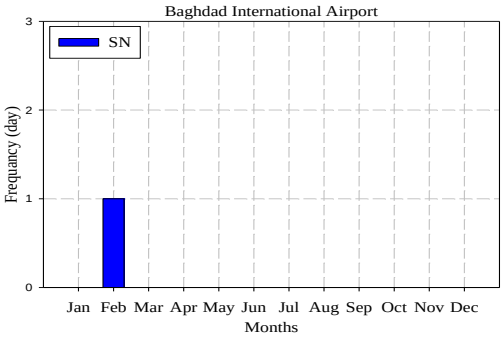


Figure 12. Snowfall (SN) at Baghdad International Airport for the year 2020.

The northern regions, including the city of Erbil, are record snowfall in varying amounts. Erbil International Airport monitoring station did not record snowfall during 2019, while 3 cases were recorded during Feb. 2020. See Figure 13.

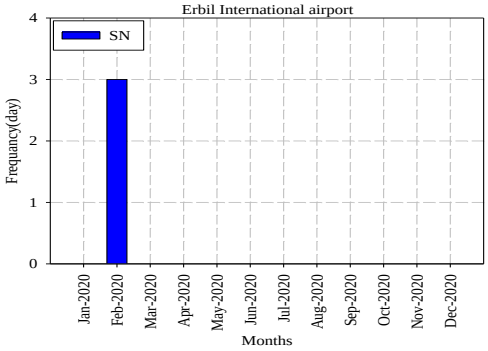
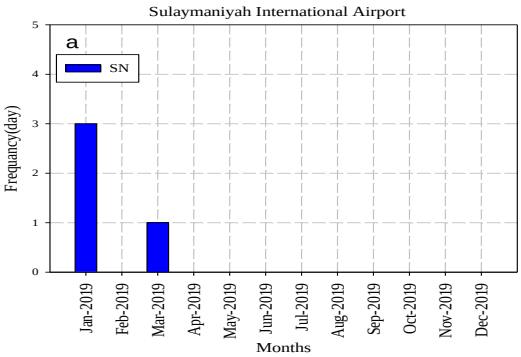


Figure 13. Snowfall (SN) at Erbil International Airport monitoring station for the year 2020.

The monitoring station of Sulaymaniyah International Airport recorded about 10 observations of snowfalls during the study period, which were in Jan., Feb., and Mar., with the most frequent case in Feb., and the least in Mar. See Figure 14.



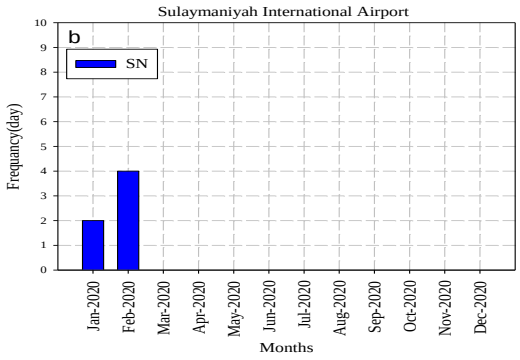


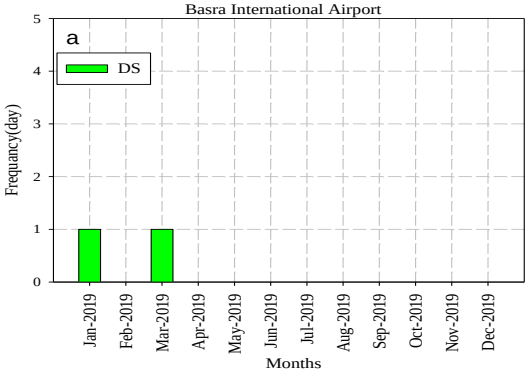
Figure 14. Snowfall (SN) at Sulaymaniyah International Airport monitoring station (A.2019), (B.2020).

Finally, Najaf, Basra International Airport monitoring station did not record any snowfall during the study period.

Estimating the frequency of Dust storms

Iraqi cities, including Basra, are record the occurrence of dust storms. Basra International Airport monitoring station recorded 13 dust storms during the study period, concentrated in Jan., Mar., May., Sep., and Nov. Dust storms cause a deterioration in the horizontal visibility, which leads to the closure of the airspace of the airport and the postponement of dozens of civil aviation flights, as the airspace was closed for 10 hours during the study period, and the highest incidence of dust storms was in May. When the horizontal visibility was to 100 meters while the maximum wind speed reached 18 meters/sec (36 knots) at the surface. See Figure 15.

The monitoring station of Sulaymaniyah International Airport recorded the occurrence of one dust storm on 5th May 2020 that lasted about two hours, where the horizontal visibility decreased to less than 500 meters. This dust storm caused the closure of the airspace for the movement of passengers and civil aircraft. See Figure 16



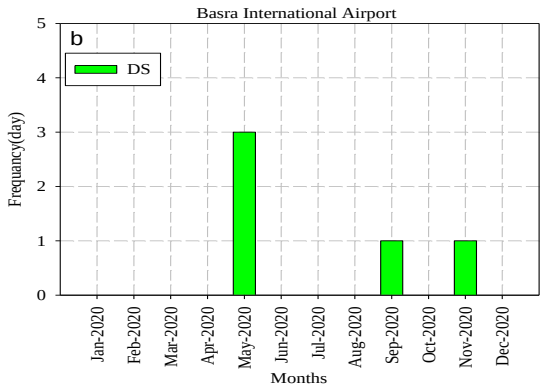


Figure 15. Dust storms (DS) at Basra International Airport monitoring station (a.2019) and (b.2020).

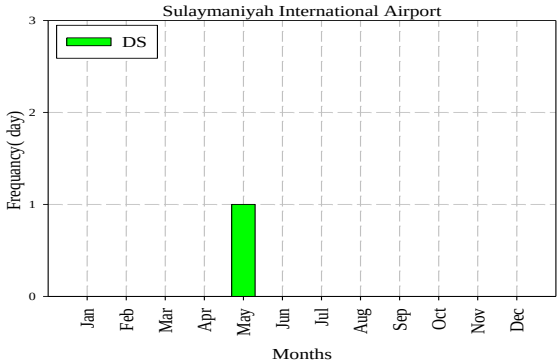


Figure 16. Dust storms (DS) at Sulaymaniyah International Airport monitoring station (2020).

Najaf International Airport monitoring station recorded only one dust storm on 6th May 2020 that lasted for two hours, in which the horizontal visibility reached zero meters at the surface and leads to the closure of the airspace to aircraft movement as shown in Figure 17.

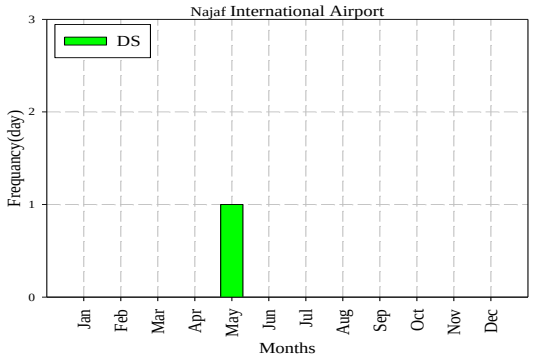


Figure 17. Dust storms (DS) at Najaf International Airport monitoring station (2020).

Baghdad and Erbil International Airport monitoring station did not record any Dust storm during the study period.

The impacts of severe weather conditions on Iraqi international airports

The figures below show the impact of severe weather conditions Thunderstorm (TS), Fog (FG), Dust Storm (DS), and Snow (SN) on Iraqi international airports that caused the closure of the airspace of the airports according to the instructions of the International Civil Aviation Organization (ICAO).

The results show that the Baghdad International Airport was significantly affected by the occurrence of fog during the years 2019 and 2020, as it was evident through the data. See Figure 18.

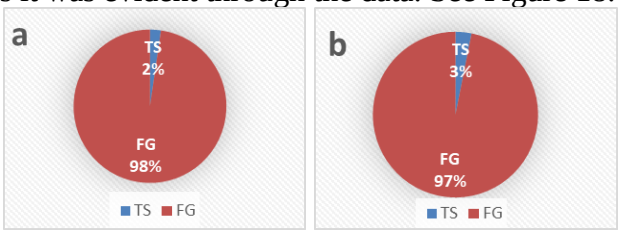


Figure 18. Number of days of airspace closure per severe weather conditions in Baghdad airport (a.2019) and (b.2020).

Erbil International Airport was greatly affected by the occurrence of thunderstorms as it is a mountainous area and the frequent occurrence of this type of storm, as the Erbil International Airport monitoring station did not record any dust storm or fog during 2019, while in 2020, there was a significant impact of fog and snow storms, while the percentage of the effect of thunderstorms. See Figure 19.

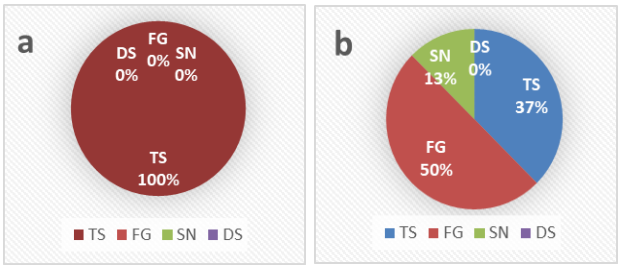


Figure 19. Number of days of airspace closure per severe weather conditions in Erbil airport (a.2019) and (b.2020).

In 2019 at the monitoring station of Sulaymaniyah International Airport, there was a significant impact of thunderstorms, while the impact of snow was minimal, while in 2020, the effect of fog was very large compared to the occurrence of thunderstorms and snow. See Figure 20.

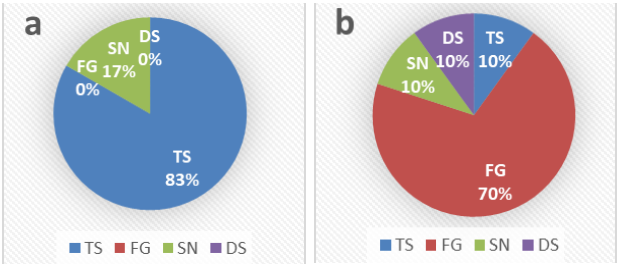


Figure 20. Number of days of airspace closure per severe weather conditions in Sulaymaniyah airport (a.2019) and (b.2020).

At Najaf International Airport monitoring station, the impact of fog was significant during the year 2020, while dust and thunderstorms had a small impact. See Figure 21.

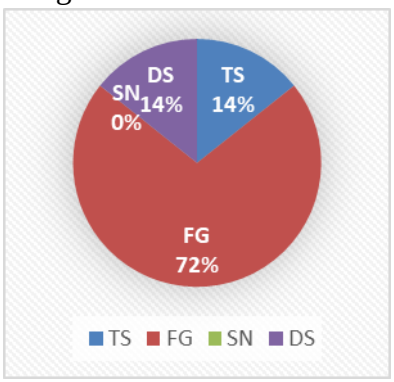


Figure 21. Number of days of airspace closure per severe weather conditions in Najaf airport 2020.

As for the Basra International Airport monitoring station, the fog had a major impact, followed by the impact of dust storms during 2019 and 2020. See Figure 22.

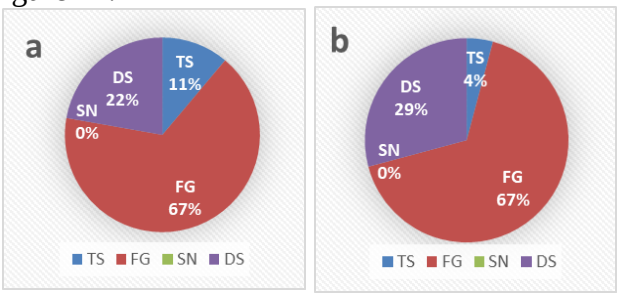


Figure 22. Number of days of airspace closure per severe weather conditions in Basra airport (a.2019) and (b.2020).

Synoptic analysis of extreme weather elements (case study).

The map in Figure 23a shows a high-pressure system that affected the Middle East and caused fair weather across the region, the high pressure associated with light wind and clear sky, led to radiation fog, where the criteria for fog is a light wind and clear sky and occurs in the early morning. Figure 23b shows the temperature, wind speed and direction at a flight level of 30,000 feet approximately 9200 meters, which is equivalent to

300 millibars. The map shows that the wind is northwesterly at a speed of more than 90 knots, and the temperature was -42 ^{0}C.

Figure 23c shows the presence of fog at the control station at Baghdad International Airport, where it is noted that the horizontal visibility is very low (100) meters, which led to the closure of the airspace due to the lack of clarity of vision, which caused the delay of many flights. Fog arises when the temperature is very low, it can reach 0^{0}C, with 100% high humidity and calm winds, in addition to having enough moisture in the soil.

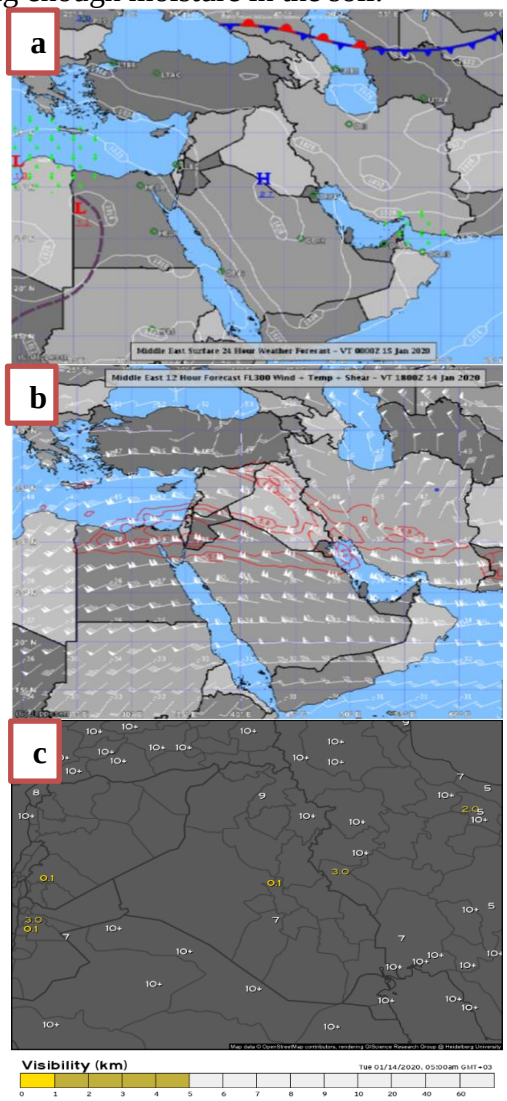
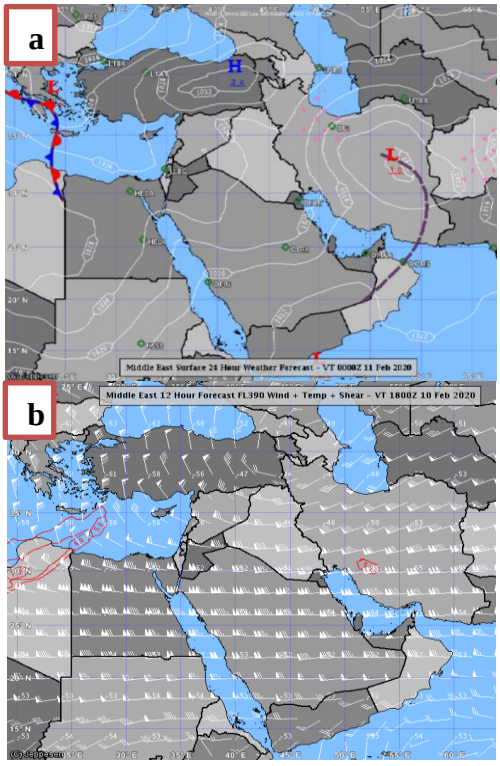


Figure 23. Synoptic analysis of the occurrence of fog at Baghdad International Airport Jan 14, 2020 [19].

Figure 24a shows high atmospheric pressure over Turkey that impact Iraq on 11th Feb. 2020 which caused a drop in the temperature to 0°C on the same day, Snow fell in the capital Baghdad and lasted for several hours, but it did not cause the closure of the airports, and the operations of take-offs and landings of aircraft continued at Baghdad International Airport.

Figure 24b shows the temperature, wind speed and direction at an altitude of 39,000 feet (12,000 meters). Approximately 200 millibars, with the wind speed reaching nearly 90 knots in a northwesterly direction, with temperatures as low as -48 ^{0}C. Figure 24c shows the recording of snowfall at Baghdad International Airport station. Figure 25a shows the synoptic maps that indicates a case of atmospheric instability, the sea level pressure map shows a low-pressure system situated over Syria, Jordan, north Saudi Arabia, and Iraq, and the upper air map shows a closed cyclonic circulation as a sign of instability. The cold advection at the upper level and thermal advection associated with low pressure at the surface caused unstable weather, where a heavy thunderstorm with showers over Iraq and neighboring countries. Figure 25b shows the temperatures, speed and wind direction at an altitude of 30,000 feet (9200 meters), 300 millibars, where the wind speed reached more than 50 knots in a southwesterly direction with a temperature of -40^{0}C over Iraq. Figure 25c shows the locations of thunderstorms as they were found in the central and southern regions of Iraq. Figure 25d shows the time of occurrence of thunderstorms at the Baghdad International Airport monitoring station.



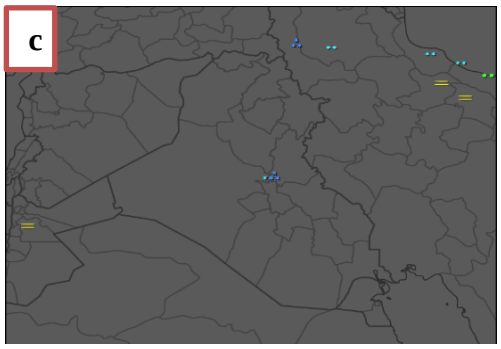


Figure 24. Synoptic analysis of Snowfall at Baghdad International Airport 11 Feb 2020 [19].

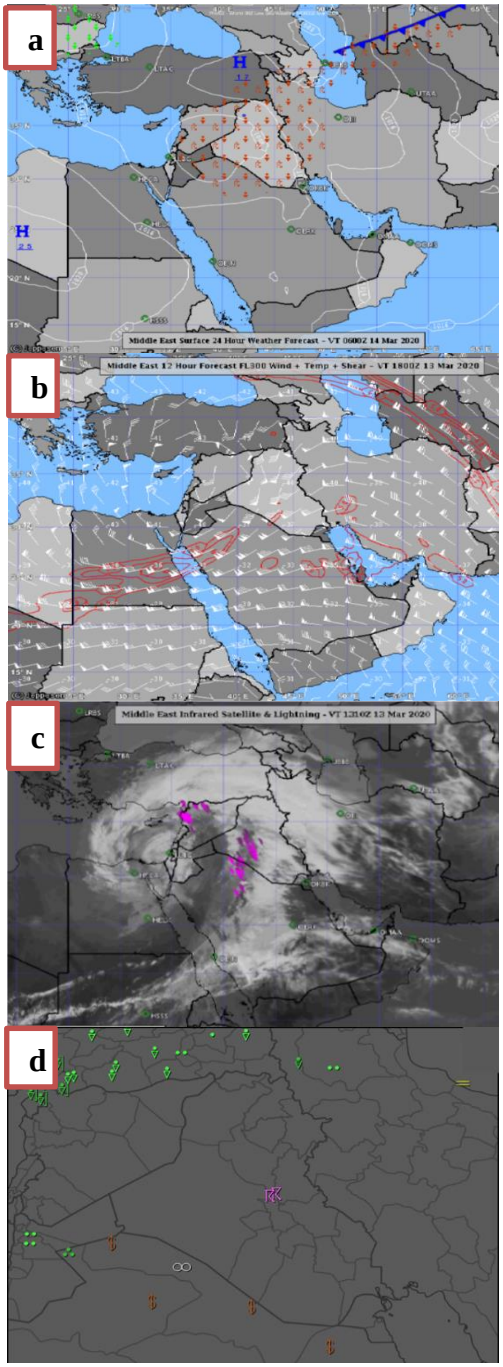
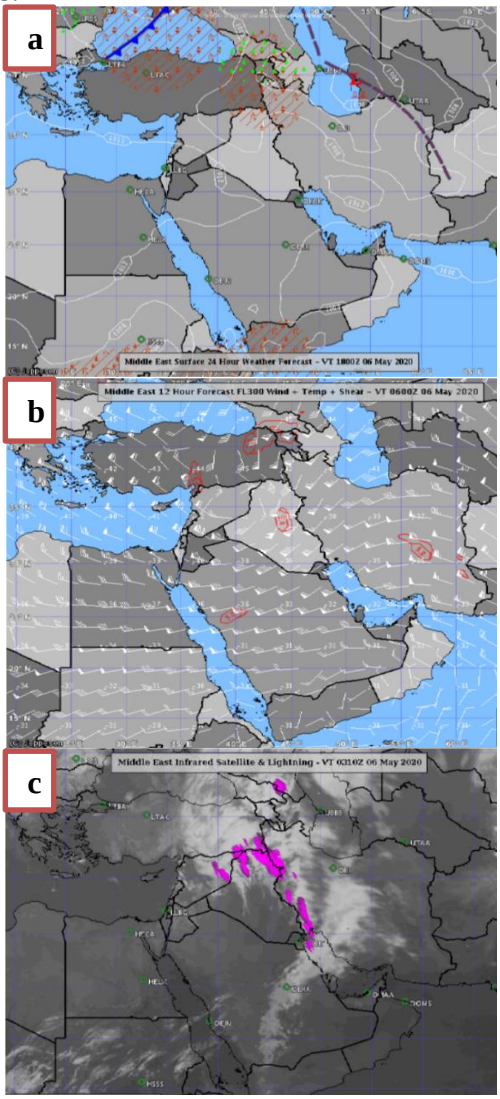


Figure 25. Synoptic analysis of occurrence of thunderstorms at Baghdad International Airport 13 Mar 2020 [19].

Figure 26a case of atmospheric instability affected the northern parts of Iraq, where a low-pressure system from Europe caused thunderstorms and rainfall events, while the middle and southern parts of Iraq were under the influence of a high-pressure system from North Africa, which causes unstable weather and occurrence of dust storms. Figure 26b shows the temperatures, speed and direction of the wind at an altitude of 30,000 feet (9200 meters), 300 millibar. Where the wind speed exceeded 100 knots in direction southwesterly with a temperature of -35 ^{0}C. Figure 26c shows the weather in Iraq via satellite images, showing the locations of thunderstorms. Figure 26d shows a state of instability in the central and southern regions of Iraq, where the monitoring station of Basra Airport and Najaf International Airport recorded a decrease in the range of horizontal visibility due to dust storms.



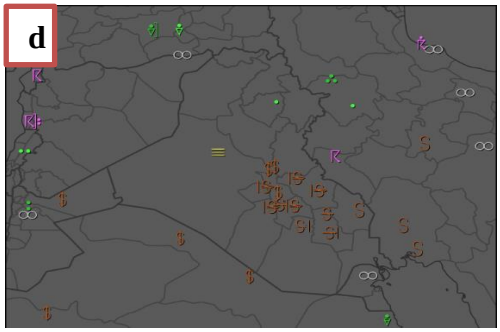


Figure 26**.** Synoptic analysis of the occurrence of Dust Storm at Basra Airport and Najaf International Airport 6 May 2020 [19].

CONCLUSIONS

This paper discusses the most important weather factors affecting air traffic in Iraqi airports, and their effects on canceling or postponing flights in order to make decisions that are in the public interest to reduce the postponement of flights. Some conclusions were reached:

- The occurrence of thunderstorms at a high rate at the monitoring station of Erbil Airport and Sulaymaniyah International Airport during the year 2019 and at a high rate, while during the year 2020, the fog had the largest share of impact.
- Fog had a significant impact on Baghdad International Airport in 2019 and 2020, while the impact of thunderstorms was weak.
- The northern region was characterized by snowfall, while it was non-existent in the southern region of Iraq.
- At the monitoring station of Basra and Najaf international airports, the impact of fog was significant on-air navigation, followed by the impact of dust storms during 2019 and 2020.
- The airspace of the airports was closed for dozens of hours during the study period due to weather phenomena (fog, thunderstorm, dust storm) that caused a decrease in the range of horizontal visibility, which led to the postponement and cancellation of dozens of flights.

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