



Review on Cyclone Shaheen in the Sultanate of Oman

Ibrahim O. R.^{1,2} · Salma Al Maghawry¹

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Abstract

There are mainly two types of cyclones, mid-latitude cyclones, and tropical cyclones. Mid-latitude cyclones form when the temperature difference is large between two air masses, where the two masses do not blow in the same direction, instead they blow past each other. On the other hand, tropical cyclones are what form over tropical oceans and create a strong storm with a low-pressure center. Hurricanes, typhoons, and tropical cyclones are all tropical cyclones in different geographical parts of the earth. Regardless, they remain the most damaging storms on earth. In Oman, they are called tropical cyclones, since that is the name given for cyclones in the Indian Ocean. However, each tropical cyclone has an individual name to make the identification process easier. Hence, why the tropical cyclone that hit Oman in October 2021 was referred to as Cyclone Shaheen. The cyclone caused very high amounts of precipitation and severe damage to the infrastructure of several regions in the Sultanate of Oman. This paper aims to review the course of the cyclone and its development, identify, and collect the recorded hydrological data, assess the damage caused, as well as assess the way the Omani government dealt with this natural disaster.

Keywords Shaheen · Cyclone · Oman · Review · Flood

Introduction

Cyclones are a form of natural disaster that threatens life not just when they are formed but during the forming process as well. A cyclone hitting a coastal area means storms, flooding, extremely strong winds, and lightning can be expected. It consists of a system of winds rotating around a low-pressure center; this rotating air rises and cools in the process which causes clouds and high amounts of precipitation (Rayburntours 2020).

Considering that Oman is surrounded by sea from two sides and has a coast length of almost 3165 km, it has a relatively rich history when it comes to tropical cyclones and storms (Abri 2021). During the past 50 years, there have been over nine severe tropical cyclones that caused losses of lives and material damage. In June 1977, a

cyclone that was the deadliest yet struck Masirah Island and South Omani areas killing over 100 people and destroying the homes of thousands of people. In June 1996, another tropical storm named (02A) also struck Masirah Island, killing three people and damaging buildings. In May 2002, an uncommon tropical cyclone struck Dhofar, causing the heaviest rainfall to Dhofar in 30 years. Five years later, Cyclone Gonu — the most famous cyclone — killed 50 people in the span of 2 days (5th to the 7th of June) and caused severe damage that was estimated to be 1.5 billion Omani rials, making it the most expensive natural disaster yet. Other powerful tropical cyclones were Cyclone Phet in May 2010, Cyclone Mekunu in May 2018, Cyclone Hikaa in September 2019, and finally Cyclone Shaheen in October 2021. Table 1 shows a comparison between the previously mentioned cyclones, and Fig. 1 shows some of the severe cyclones that struck Oman in the past 50 years. In the light of the aforementioned, it is crucial to study and analyze Cyclone Shaheen's hydrological data as well as assess the damages caused by it to move forward with plans to improve flood mitigation systems in the country.

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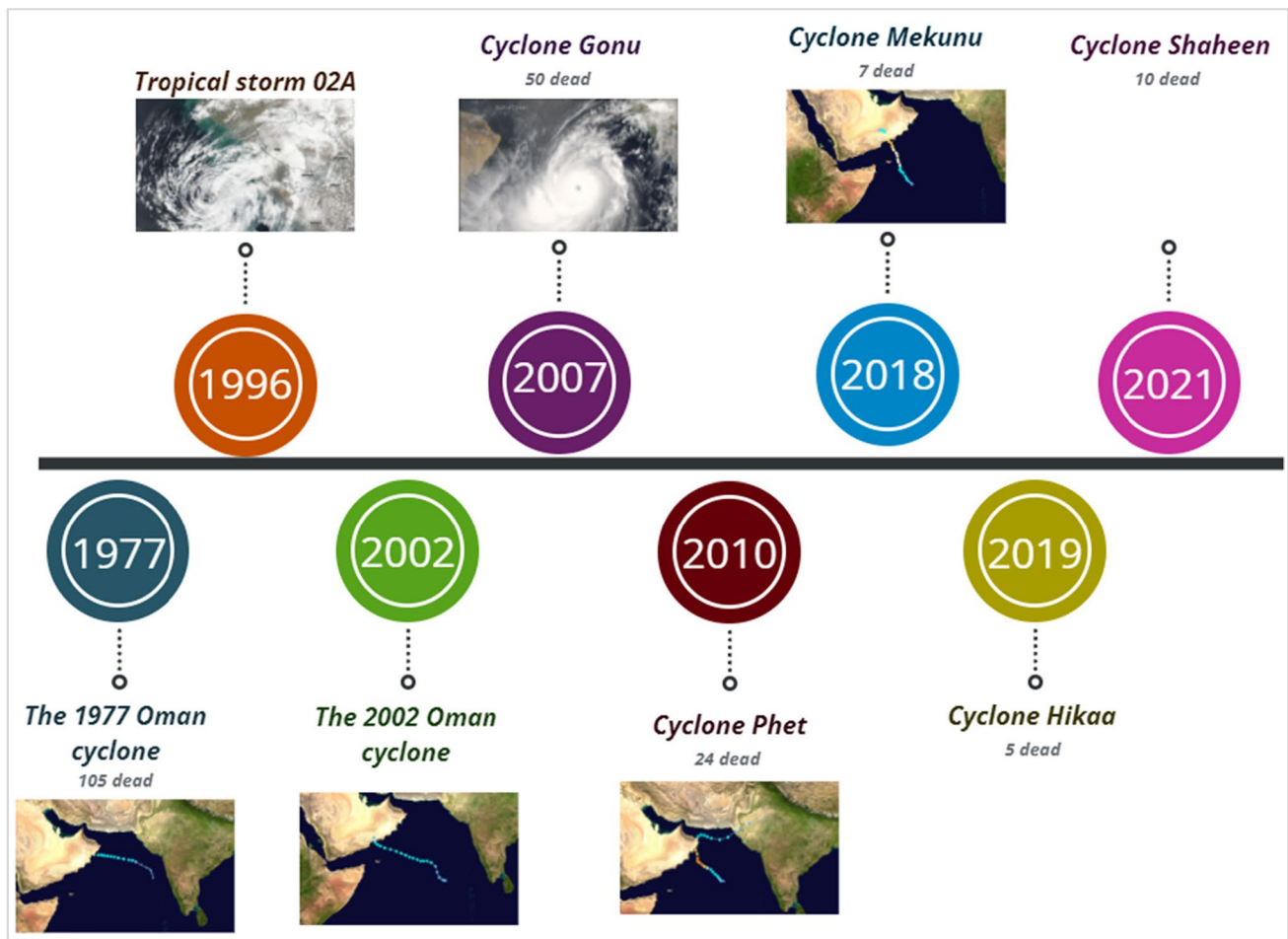
✉ Ibrahim O. R.
oibrahim@su.edu.om

¹ Faculty of Engineering, Sohar University, Sohar, Oman

² Hydraulic and Irrigation Structures Department, Alexandria University, Alexandria, Egypt

Table 1 Some severe cyclones that struck Oman in the past 50 years (Abri 2021)

Name	Month-year	Areas affected	Max precipitation	Max wind speed
The 1977 Oman cyclone	June 1977	Masirah Island + south of Oman	430 mm over 24-h period	230 km/h
Tropical storm 02A	June 1996	Masirah Island	200 mm	75 km/h
The 2002 Oman cyclone	May 2002	Dhofar	58 mm over 24-h period	65 km/h
Cyclone Gonu	June 2007	North of Oman	943 mm in 2 days	270 km/h
Cyclone Phet	May 2010	Eastern Oman	603 mm over 24-h period	230 km/h
Cyclone Mekunu	May 2018	Dhofar	617 mm over 4 days	185 km/h
Cyclone Hikaa	September 2019	Duqm	80 mm	140 km/h
Cyclone Shaheen	October 2021	North of Oman	369 mm over 24-h period	102 km/h

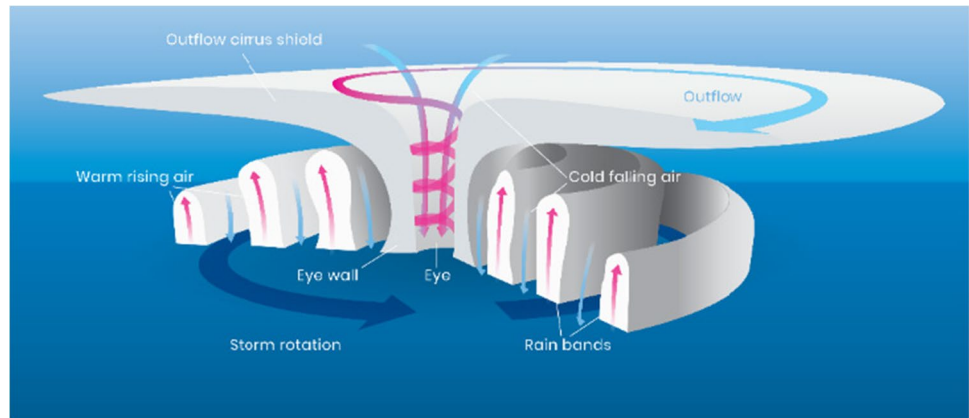
**Fig. 1** Timeline showing the satellite images of cyclones that struck Oman in the past 50 years

Stages of a cyclone

The way a cyclone works is that first, a tropical low disturbance occurs. The warm air that is filled with water rushes towards the low pressure to rise upward to form clouds and thunderstorms. In the first stage — which is the tropical

disturbance — winds have a speed of fewer than 37 km/h. When the disturbance develops into a tropical storm, the wind speed rises to 62–117 km/h. When wind speed exceeds the 119-km/h limit, it is classified as a cyclone, meaning that wind is the main difference between a tropical storm and a cyclone (Rainbow international n.d.).

Fig. 2 Cyclone anatomy (Rayburntours, 2020)



Anatomy of the cyclone

The anatomy of the cyclone begins with the wall of clouds around the pressure disturbance area, which is called the eyewall. Within the eyewall occur the highest amounts of precipitation and the strongest wind. The center of the cyclone is the eye of the cyclone, and within it, the wind and the precipitation amounts are at their lowest; hence, it is why it is classified as the calmest region of the storm. Away from the eyewall, there are intense thunderstorms that are called spiral rainbands in which the rainfall amounts and wind speed are very high (Rayburntours 2020). Figure 2 shows the anatomy of cyclones.

Classification of cyclones

According to (Lumen learning n.d.), Table 2 shows the classification of cyclones depending on the wind speed.

Cyclone Shaheen path

A week before when Cyclone Shaheen struck Oman, another cyclone called Cyclone Gulab struck India and caused high amounts of rainfall. Shaheen started as a

well-marked low pressure that was traced back to the remains of Cyclone Gulab; this low pressure moved out of the western Indian Ocean into the Arabian Sea; once it entered the Arabian Sea, it started to strengthen and was named Shaheen. Figure 3 shows the path of the cyclone from the point it originated in the Indian Sea to the point it struck the Omani coastal areas(Hafiz 2021).

On Wednesday, September 29th, the Omani News Agency reported that they have been detecting what looks like the beginning of a tropical storm in the Arabian Sea and expecting it to fully develop in the next 36 h (Ather newspaper 2021). On the same day, the expected course of the storm is announced, as shown in Fig. 4, showing how the cyclone is developing and getting stronger as it reaches the land, which indicates that the level of danger is rising, since precipitation amounts and wind speed are increasing significantly.

On Friday morning, the Center of Meteorology announces that the eye of the tropical storm Shaheen is 590 km away from the Omani coasts depending on the satellite-obtained images, as shown in Fig. 5 (the arabian stories 2021). Later that afternoon, it was announced that the tropical storm will develop into a first-degree cyclone and is expected to stick to the Omani lands on Sunday the first of October.

On Saturday morning, the 2nd of October, the cyclone is 500 km away from Muscat — the capital city of Oman — and is moving towards the north and south Al Batinah regions, as shown in Fig. 6 (Hafiz 2021). It meant that the main danger

Table 2 Classification of cyclones (Lumen learning n.d.)

Category	Wind speed (km/h)	Estimated damage
1 (weak)	119–152	Above normal; no read damage to structures
2 (moderate)	154–177	Some property damage; considerable damage to vegetation
3 (strong)	178–209	Some buildings were damaged; mobile homes destroyed
4 (very strong)	210–251	Complete roof failure on small residences; major beach erosion of beach areas
5 (devastating)	Over 251	Complete roof and some building failure on most residential and industrial buildings

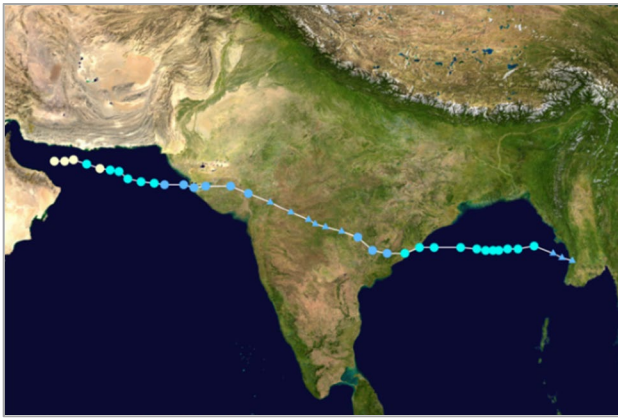


Fig. 3 Cyclone Shaheen path (Hafiz, 2021)

was going to be on the north and south Al Batinah and not on the capital city. The cyclone continued moving towards the coast reaching 320 km away at 1 p.m., Saturday, then 130 km at 1 a.m., Sunday, meaning that it moved almost 190 km in 12 h only. At 7 a.m., Sunday, Muscat and south and north Al Batinah started getting high intensity of precipitation and very strong winds as the eye of Cyclone Shaheen was only 80 km away from Muscat (Ather newspaper 2021).

On Sunday evening, the news agency announced that the eye of the cyclone will enter the land between the states of Musanah and Suwaiq in the upcoming hour. At 8 p.m., the tropical cyclone enters the land accompanied by very intense rainfall and strong wind that reaches 120–150 km/h on the eyewall of the tropical cyclone, as shown in Fig. 7.

After entering the land, Cyclone Shaheen was classified as a tropical storm instead of a tropical cyclone as the wind speed decreased to 116 km/h. As Shaheen continuously lost

its wind intensity, by Monday afternoon, it was classified again as a depression over western Oman. Whatever was left of Cyclone Shaheen was torn apart by Monday night due to the very dry air in the southwestern area of Oman. The tropical storm was announced to be officially over by the Omani news agency on Monday the fourth of October at 2 p.m.

Observation and data collected

The precipitation period started on Saturday evening until Monday evening (almost 48 h). Rainfall amounts continued until 5 p.m. on Sunday, the third of October. The amounts of precipitation in different locations in Oman from the 2nd to the 3rd of October are shown in Fig. 8, according to Khalaf (2021).

Globally, Suwaiq is the first place in the maximum precipitation amounts during 24 h from Sunday 6 p.m. to Monday 6 p.m. with the record of 305.8 mm, as shown in Fig. 9 (Al-Ain 2021). Cyclone Shaheen caused extremely high winds that created waves up to 10 m along the northern coast of Oman (Hafiz 2021). According to Gilbert (2021), the wind speed reached 116 km/h as a peak record.

Discussion

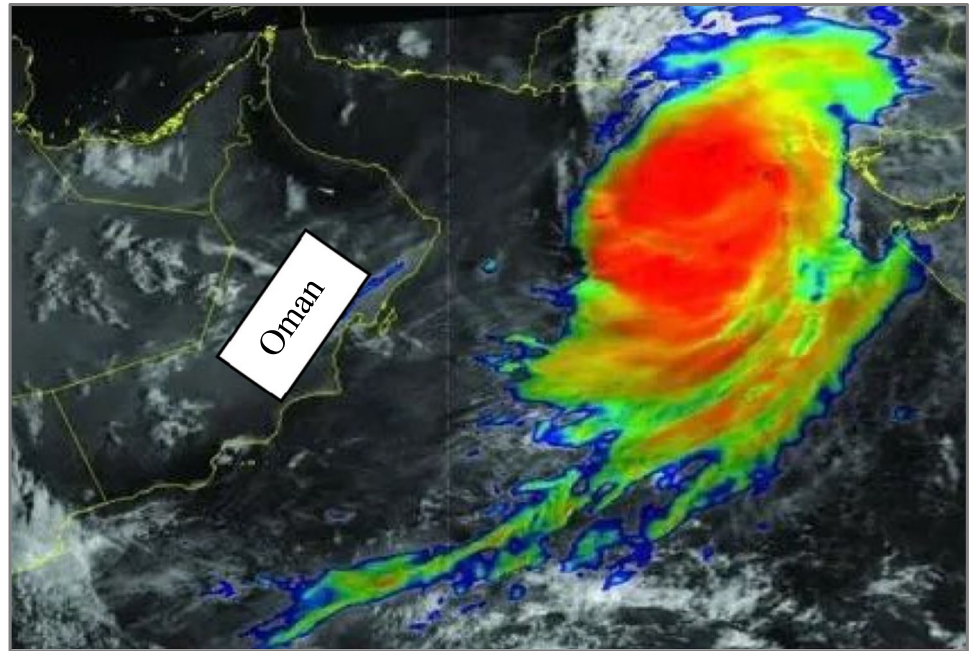
Tropical storms and cyclone seasons

Looking back at the timeline of tropical storms and cyclones in Table 1, it can be observed that tropical

Fig. 4 The expected course of the tropical Cyclone Shaheen (Arab News, 2021)



Fig. 5 The eye of the cyclone 590 km away from the Omani coasts (The Arabian stories, 2021)



cyclones in Oman usually occur in the second half of the year, mostly during June (Al-Maskari 2012). Studies have shown that tropical storms in the Arabian Sea have two main cyclone seasons, the pre-monsoonal period from May to June and post-monsoonal from October to

November, which means that Cyclone Shaheen is within the second season (post-monsoonal). Figure 10 shows the frequency of tropical cyclones affecting the Arabian Sea in the years 1801 till 2007 in which the two seasons are observed.

Fig. 6 The eye of the cyclone before entering the land in between the states of Musanah and Suwaiq (Hafiz, 2021)

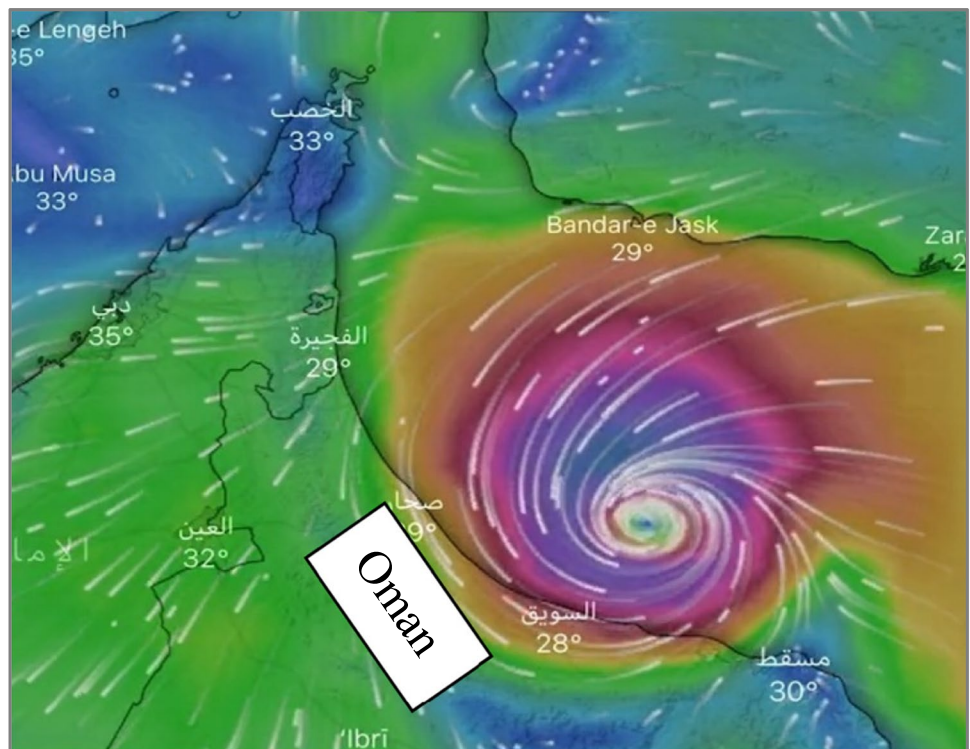


Fig. 7 The eye of Cyclone Shaheen entering the land in between the states of Musanah and Suwaiq (Al-Maskari 2012)

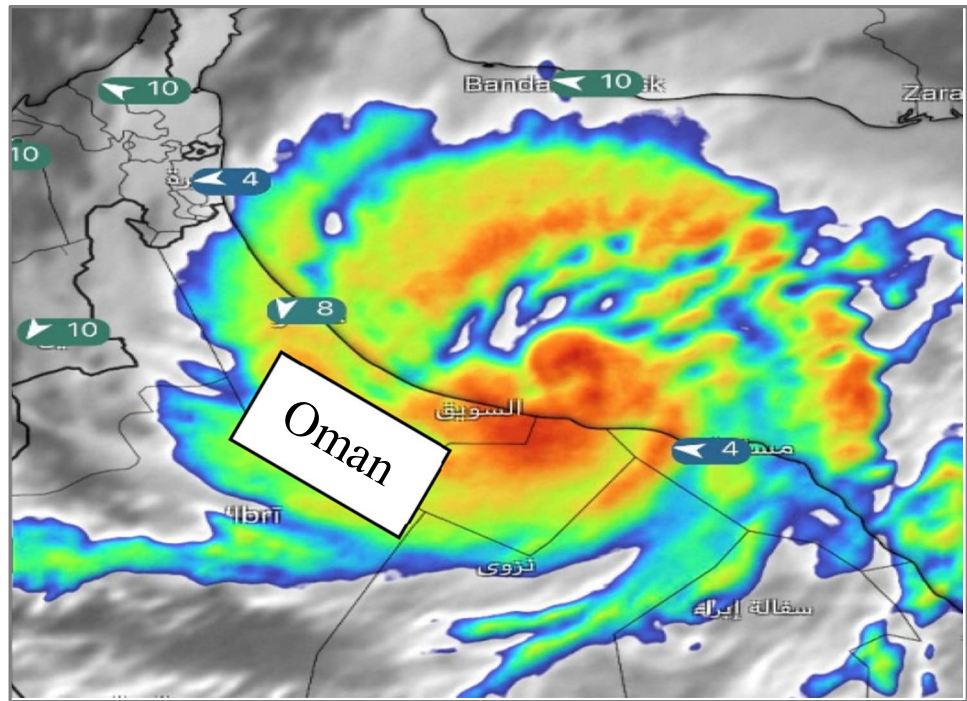
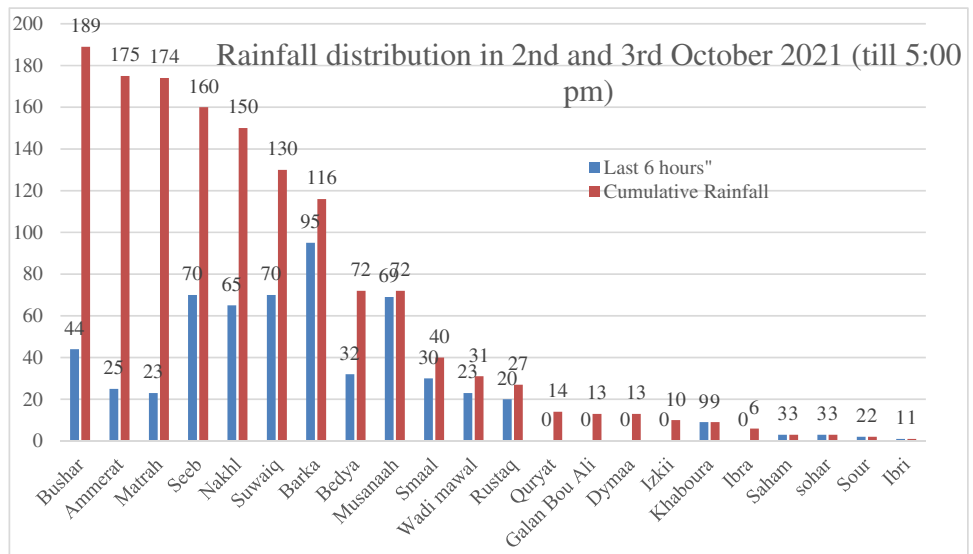


Fig. 8 Amounts of rainfall on the 2nd to 3rd of October recorded by rain gauges in different regions of Oman (Khalaf, 2021)



Cyclone Shaheen records

Cyclone Shaheen caused the high intensity of precipitation with the maximum amount of 365 mm which is higher than the last recorded severe cyclone (Cyclone Hikaa) in Duqm (80 mm), but lower than the last cyclone that hit northern Oman (Cyclone Gonu) with the rainfall amount of 610 mm (Al-Ain 2021). Figure 11 shows a graph representing the amounts of rainfall over the period of 24 h in the years of the previously mentioned cyclones. Fortunately, the wind speed was relatively lower than

Cyclone Hikaa in 2019 and Gonu in 2007 with a record of 116 km/h (Abri 2021).

Advantages and disadvantages

There is no doubt that the main damage Cyclone Shaheen has caused is the loss of lives. On Sunday, it was reported that the body of a missing child was found in Muscat, and another two workers were found dead in the industrial area of Muscat that was damaged due to the intensity of rain and

Fig. 9 Maximum global precipitation amounts recorded from 3rd to 4th of October (Al-Ain, 2021)

Maximum Precipitation Last 24h - 10/04/2021 at 06:00 UTC			
No.	Location	Station ID	Amount
1	Suwaiq (Oman)	41272	305.8 mm
2	Guiuan (Philippines)	98558	275 mm
3	Rangpur (Bangladesh)	41859	265.2 mm
4	Saidpur (Bangladesh)	41858	246.4 mm
5	Maasin (Philippines)	98648	222 mm
6	Borongan (Philippines)	98553	195 mm
7	Longkou (China)	54753	182.1 mm
8	Evora / C. Coord (Portugal)	08558	174 mm
9	Sao Jorge/Aerodrome (Portugal)	08510	167 mm
10	Kosrae Airport Vice Lelu, Kosrae Atoll, Caroline Is. (Micronesia, Federated States of)	91356	166.8 mm
11	Tayabas (Philippines)	98427	165.5 mm
12	Ratcha Buri (Thailand)	48464	165 mm
13	Viana Do Castelo-Chafe (Portugal)	08551	159.1 mm
14	Mactan (Philippines)	98646	145 mm
15	Linjiang (China)	54374	144.7 mm

Fig. 10 Frequency of tropical cyclones and storms in Oman (Al-Maskari 2012)

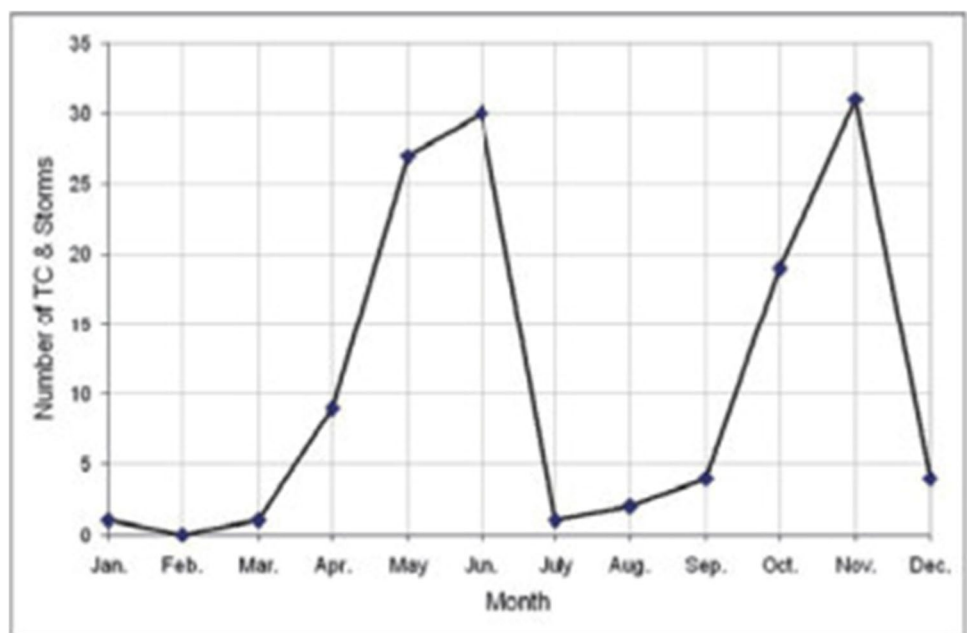


Fig. 11 Amounts of rainfall over 24 h caused by previous cyclones that struck Oman over the past 50 years

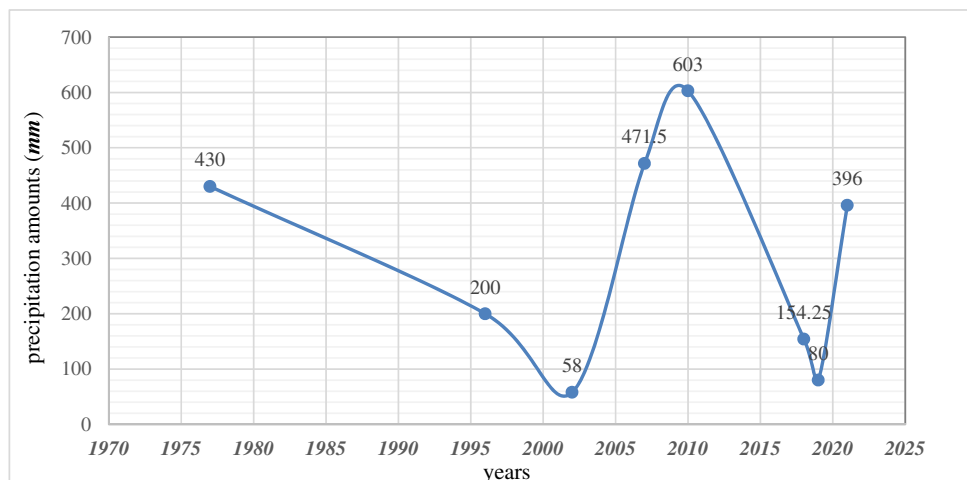




Fig. 12 Damage Cyclone Shaheen did to the capital city, Muscat (Jazeera, 2021)

wind. On Monday, seven more people were announced dead in the Al Batinah region meaning that at least 10 people died because of the Shaheen disaster (BBC 2021). Moreover, buildings were destroyed, and highways and roads were completely flooded due to Cyclone Shaheen. People were not allowed to leave for work or school and even flights were suspended during the 2 days of the cyclone. Examples of the damage caused by Cyclone Shaheen are shown in Figs. 12 and 13 (Jazeera 2021) (BBC 2021).

There are several advantages to Cyclone Shaheen; the most obvious one is that Wadis all through Muscat and Al Batinah were flowing with rainfall water, and dams were overflowing as well, which will cause a boost in the agriculture industry since flood evens help significantly in fertilizing soil (Charabi 2010). Furthermore, the high amounts of precipitation and the intense runoff amounts mean that the groundwater levels have increased significantly which is very important, since groundwater is the main source of water in Oman (Al-Zadjali et al. 2021).



Fig. 13 The state of Al Khaboura region after the cyclone on Monday, October 4th (BBC, 2021)



Fig. 14 Omani air forces rescuing people in Al Khaboura region (Gilbert, 2021)

The government's plans and preparation

The Omani government started warning people starting from Sunday, the 26th of September when there were only signs of the possibility of a tropical storm in the Arabian Sea. On Sunday evening, the 3rd of October, more than 5000 people were evacuated into 80 shelters, and the national multi-hazard early warning system has alerted residents that there was a risk of thunderstorms. People were also urged to avoid Wadis and low-lying areas (Gilbert 2021). After the cyclone entered, armed forces started rescuing people who are trapped with helicopters and are restoring damaged roads, as shown in Fig. 14.

Since Oman's history is filled with cyclones, it is recommended that more shelters in less likely to be damaged areas should be prepared for disasters like this. The government should also update their data regularly regarding the frequency of tropical storms and the expected amounts of precipitation to deal with them. A special budget should also be prepared in case of natural disasters to rebuild and restore damaged facilities, buildings, and roads.

Conclusion

Cyclone Shaheen struck Oman's North Coast on the 2nd and 3rd of October and entered between the states of Musanah and Suwaiq at 8:00 p.m. on Sunday, October 3rd, killing around 10 people and causing severe damage to several states. The maximum recorded rainfall amount was 369 mm for 24 h; the maximum recorded wind speed was 116 km/h, and the maximum recorded wave height was 10 m. Overall, further studies are recommended to analyze precipitation amounts and update the government's database regularly; as well as evaluate the performance of satellite products — like the Global Satellite Mapping of Precipitation (GSMaP)

products and the Tropical Rainfall Measuring Mission (TRMM) — in predicting the amounts of rainfall to be able to deal with tropical cyclones in the best way possible and prepare the most beneficial flood mitigation and protection plans in order to — hopefully — avoid the loss of lives.

Declarations

Conflict of interest The authors declare no competing interests.

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