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MEDITERRANEAN CYCLONES AND OFFSHORE STRUCTURES

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Abstract - *The so-called Medicanes (Mediterranean hurricanes) are mesoscale and warm-core Cyclones that show great similarities with Tropical Cyclones. Due to the difference in sea-state conditions from one region to another during the passage of any Cyclone, knowing the characteristics of the local waves of a specific region are becoming an important subject, which may lead to some emergency measures such as evacuation of fixed offshore platforms, preventing the movement of ships, closing the ports, ...etc. This paper presents a study on Cyclone of October 2019 and its associated waves, as well as determining its classification. In addition, the most probable maximum wave height (H_{max}), caused by the Cyclone, was calculated and compared to the H_{max} used in the design of existing fixed platforms in the study area. The results showed that the H_{max} due to the cyclone is less than H_{max} for the existing fixed platforms in this region and it does not need to be evacuated.*

The results of the present study will be highly useful to investigate any cyclone that occurs in the Mediterranean basin, which may lead to a change in the design criteria for this region in future.

Key Words: Cyclone, Medicane, Fixed platforms, Maximum wave height, Mediterranean basin.

1. INTRODUCTION

In meteorology, the term "Cyclone" is a large scale air mass that rotates around a strong center of low atmospheric pressure called "Cyclone Eye" [1]. The cyclone applies to numerous types of low pressure areas [2] (e.g. the tropical, extratropical and subtropical cyclones), which has a counter clockwise flow of air in the Northern Hemisphere as the air fills in to this low-pressure area [3].

In 1950, meteorologists were agreed to classify the cyclones as tropical and extratropical cyclones. In 1972, they were officially recognized by the National Hurricane Center (NHC) affiliated with the National Oceanic and Atmospheric Administration (NOAA). Beginning in 2002, subtropical cyclones received names from the official tropical cyclone lists in the North Atlantic, South-west Indian Ocean, and South Atlantic basins. The subtropical cyclones have broad wind patterns with maximum sustained winds located farther from the center than typical tropical cyclones, and have no weather fronts linked into their center [4] [5].

The subtropics are geographic located roughly between the latitude 23.5° and 40.0° inside the temperate zones (from latitudes 35 to 66.5°) north and south of the Equator. According to Köppen climate classification, the Mediterranean climate is considered as a subtropical climate which is often characterized by hot dry summers and cooler winters with rainfall [6] [7].

In September 2019, meteorological agencies warned that a strong cyclone would hit the eastern Mediterranean, originating in southern Cyprus, moving south towards Egypt's northern coast and then heading east towards Palestine.

NASA agency said that a low-pressure area appeared over the Mediterranean Sea in late October 2019 south Cyprus, forming an unusual type of storm often called a "Medicane". This storm threatens to bring rough seas, tropical-storm strength winds, and potentially up to 200 mm of rain to the region. NASA picked up the Medicane image in October 26, 2019 by using the MODIS satellite instrument (Figure -1). NASA pointed out that the reason for such an unusual phenomenon in the Eastern Mediterranean basin is the exceptionally high-water temperatures of this location than usual at the same time of year (approximately 2 degrees Celsius), which is the driving force for the formation of such a cyclone [8].

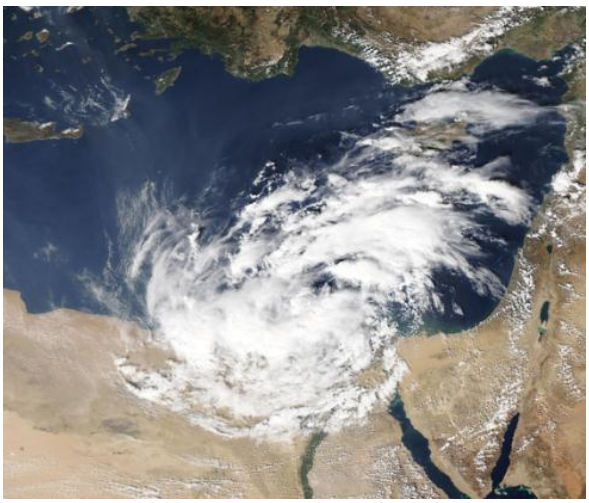

Fig -1: Rare Storm over Mediterranean Sea, Aqua-MODIS Satellite Image 2019 [8].

The aim of this study is to investigate the cyclone characteristics and assess its classification as well as its impact on the existing fixed offshore platforms located in the study area. This paper is organized as follows: the next section introduces Mediterranean basin overview. Section

3 describes the study area and data description. Section 4 presents the results and discussion. Finally, conclusions are reported in the last section.

2. MEDITERRANEAN BASIN OVERVIEW

The Mediterranean basin is an area particularly prone to the generation of low-pressure systems [9]. In some regions, the regional name for severe tropical cyclones that form in the northwest Pacific Ocean are called "Typhoons", while in the northeast Pacific Ocean and northern Atlantic are called "Hurricanes" [10]. In other regions, these are called a "Tropical Cyclones", "Severe Tropical Cyclones" or "Severe Cyclonic Storms" [11]. Mediterranean Cyclones are meteorological phenomena observed over the Mediterranean Sea, often referred to as "Medicanes" (abbreviation for the **Med**iterranean Hurri**canes**) and sometimes also as Mediterranean Tropical-Like Cyclones (TLC).

Generally, the occurrence of Medicanes has been described as not a rare phenomenon. The Medicanes form predominantly over the western and central Mediterranean Sea while the area east of Crete (Greek Island) is almost devoid of tropical-like cyclones [12] [13]. The development of TLCs can occur year-round, with activity historically peaking between the months of September and January, while the counts for the summer months of June and July are the lowest [12] [13] [14].

The Hellenic National Meteorological Service (HNMS), in the Greek area, is one of the largest governmental agencies responsible for Mediterranean meteorology [15]. As the largest official agency covering the whole Mediterranean Sea, HNMS called this phenomenon "Mediterranean Tropical-Like Hurricane" in its annual bulletin and – by also using the respective portmanteau word Medicane – making the term "Medicane" somewhat official [16]. A 37 Medicanes surveyed by HNMS revealed that Medicanes could have a well-defined cyclone eye at estimated maximum sustained winds between 47 Km/h (29 mph) and 180 Km/h (110 mph) [12].

Generally, most Medicanes maintain a radius of 70 to 200 km (40 to 120 mile), last between 12 hours and 5 days, travel between 700 to 3,000 km (430 to 1,860 mile), develop an eye for less than 72 hours (3 days), and feature wind speeds of up to 144 km/h (≃ 40 m/s) [17].

2.1 Notable Mediterranean Cyclones

It is known that many distinguished and damaging Medicanes occurred in the Mediterranean Sea such as the Medicane of September 1969 causing floods that killed nearly 600 people and left 250,000 homeless [18]. In September 1996, a Medicane developed in the Balearic Islands region spawned six tornadoes, and inundated parts of the islands [19]. Several Medicanes have also been subject to extensive study, such as those of January 1982, January 1995, September 2006, November 2011, and November 2014 [13] [17] [19]. The January 1995 storm is one of the best-studied Mediterranean tropical cyclones, with its close resemblance to tropical cyclones elsewhere and availability of observations [20]. Several studies have been carried out based on the observational evidence (e.g., Ernst and Matson, 1983; Rasmussen and Zick, 1987; Luque et al., 2007; Moscatello et al., 2008) and combined, model and observations (e.g., Miglietta et al., 2013; Conte et al., 2011) [21]. Table -1 shows a list of Medicane events from 1983 to 2003, their approximate times of mature phase, sizes and geographical positions [22].

Table -1: Date, Time of mature phase and Coordinates of Medicane centers from 1983 to 2003 (Tous and Romero, 2013).

Date	Time (UTC)	Coordinates		Maximum Diameter (Km)	Lifetime (hours)
		North	East		
Sep. 29, 1983	12:00	41.1	6.8	220	90
Apr. 7, 1984	06:00	36.4	19.2	230	36
Dec. 29, 1984	06:00	35.4	11.6	220	60
Dec. 14, 1985	12:00	35.5	17.6	290	54
Dec. 5, 1991	12;00	36.2	16.7	320	30
Jan. 15, 1995	18:00	36.4	19.1	300	78
Sep. 12, 1996	12;00	39.4	2.8	170	12
Oct. 6, 1996	18:00	37.2	3.9	240	90
Dec. 10, 1996	00:00	40.3	3.7	230	48
Jan. 26, 1998	12:00	36.7	17.9	250	30
Mar. 19, 1999	06:00	38.5	19.6	250	30
May 27, 2003	00:00	40.1	2.8	280	42

2.2 Categorization of Cyclones

Cyclones are categorized by measuring maximum sustained winds over either a one-minute (US-based) or ten-minute (European-based) time span during the cyclone period. This value helps determine the expected damage from a tropical cyclone, by using metrics such as the Sapphire-Simpson Hurricane Wind Scale (SSHWS).

For severe tropical cyclones (i.e. Hurricanes), Saffir-Simpson suggested scale to classify the hurricanes into five categories based on the intensities of their sustained winds as shown in Table -2.

Table -2: Saffir-Simpson Hurricane Wind Scale (SSHWS)

Category	Description	Wind speeds (1-minutes maximum sustained winds) US-based scale		
		Knots	mph	Km/h
One	Very Dangerous	64-82	74-95	119-153
Two	Extremely Dangerous	83-95	96-110	154-177
Three	Devastating Damage	96-112	111-129	178-208
Four	Catastrophic Damage	113-136	130-156	209-251
Five	Very Catastrophic Damage	≥ 137	≥ 157	≥ 252

To be classified as a hurricane, a tropical cyclone must have one-min maximum sustained wind of at least 64 kt (Category -1, Table -2).

On a few rare occasions, some Medicanes have been observed reaching the strength of a Category -1 according to Saffir–Simpson hurricane wind scale [23].

The German meteorological agency Deutscher Wetterdienst (DWD) proposed a system for forecasting and classify Tropical-Like-Cyclones in accordance with NHC classification for the northern Atlantic Ocean. DWD is suggesting a lower threshold of 112 km/h, as shown in Table -3 below, for the use of the term Medicane in the Mediterranean instead of 119 km/h as suggested by the Saffir-Simpson scale for Atlantic hurricanes [23].

Table -3: DWD Tropical-Like Cyclones Scale

Category/Description	Wind speeds (1-minutes maximum sustained winds) US-based scale		
	Knots	mph	Km/h
Mediterranean tropical depression	≤ 33	≤ 38	≤ 62
Mediterranean tropical storm	34-60	39-69	63-111
Medicane	≥ 61	≥ 70	≥ 112

The AU-Squared Weather Center (AU^{2}WS) was established in 2017 and its headquarters is located in California, USA to start tracking of Mediterranean cyclones. Table -4 shows the scale used to determine the intensity of Mediterranean cyclones created by AU^{2}WS, also known as Medicanes [24]:

Table -4: AU^{2}WS Medicane Scale

Medicane Classification	Wind speeds (1-minutes maximum sustained winds) US-based scale		
	Knots	mph	Km/h
Tropical Disturbance	≤ 23	≤ 27	≤ 43
Tropical Depression	24-33	28-38	44-62
Tropical Storm	34-49	39-56	63-92
Severe Tropical Storm	50-63	57-73	93-117
Category 1 Cyclone	64-82	74-94	118-152
Category 2 Cyclone	83-95	95-109	153-176
Category 3 Cyclone	≥ 96	≥ 110	≥ 177

3. STUDY AREA & DATA DESCRIPTION

S. Hassan (2017) pointed out to the economic importance of the offshore region of the northern coast of Egypt, as shown in Figure -2, as well as the importance of studying waves and winds in that region due to the emergence of many gas discoveries in recent years in this region, in addition, it contains many fixed offshore platforms, especially in the offshore regions of Abu-Qir and Port-Said [25].

Fig -2: Gas fields in the offshore area of the northern coast of Egypt [26].

3.1 Cyclones Data

On October 23, 2019, a Cyclone appeared in the eastern Mediterranean basin, about 123 nautical miles (228km) south of Cyprus as shown in Figure -3

Fig -3: Cyclone originating point on October 23, 2019 at 18:00 UTC (Google map)

Most reanalysis data sets are available in 6 hours intervals, whereas Medicanes occur on short timescales (ranging from 12 to 90 h). Accordingly, the Cyclone was investigated for 6 hours intervals along its path to determine some of its characteristics such as maximum wind speed (U_R) in knot at Cyclone radius and relevant significant wave height (Hs) in m as well as radius of Cyclone (R) in km as shown in details in Table -5.

Table -5: Cyclone characteristics (6 hrs intervals)

No	Date (2019)	Time UTC	Location		U_R (kt)	Hs (m)	R (Km)
			N	E			
1	Oct. 23	18:00	32 39	33 26	19	2.7	160
2	Oct. 24	00:00	33 11	32 24	19	2.7	190
3	Oct. 24	06:00	33 05	32 10	21	3.2	220
4	Oct. 24	12:00	33 10	32 05	21	3.2	240
5	Oct. 24	18:00	32 45	31 25	21	3.2	250
6	Oct. 25	00:00	32 25	30 50	23	3.9	260
7	Oct. 25	06:00	32 10	30 50	23	3.9	270
8	Oct. 25	12:00	32 05	31 10	25	4.5	270
9	Oct. 25	18:00	31 45	31 10	25	4.5	260
10	Oct. 26	00:00	31 35	31 25	25	4.5	250
11	Oct. 26	06:00	31 15	31 50	25	4.5	200
12	Oct. 26	12:00	30 55	32 50	23	3.9	170
13	Oct. 26	15:00	30 30	33 15	19	2.7	140

Fig -4: Abu-Qir and Port-Said offshore areas (Google map)

As shown in Figure -4 above, the cyclone moved to the west from point (1) to point (6) and then southward to be close to the northern coast of Egypt (near Abu-Qir offshore area) at point (7). It then moved south-east (near Port-Said offshore area) at point (9), and then continued to move south-east until it reached inland at Damietta city between points (10) and (11). Finally, it dissipated inside the Sinai at point (13).

3.2 Abu-Qir and Port-Said Data

In addition to above; the data of maximum wind speed (u) in m/s, significant wave height (Hs) in m and wave period (Ts) in second recorded for 6 hours interval in each of the offshore areas of Abu-Qir and Port-Said (Figure -4) to be synchronized with the cyclone data (in Table -5 above) during the period of this cyclone. This data provided by the Egyptian Navy Forces, Meteorological and Oceanographic Division (see Table -6).

Table -6: Wind & wave characteristics synchronized with cyclone data (6 hrs intervals)

Date (2019)	Time (UTC)	Abu-Qir offshore area			Port-said offshore area		
		Hs (m)	Ts (S)	u (kt)	Hs (m)	Ts (S)	u (kt)
Oct. 23	18:00	1.0	5	11	1.3	6	13
Oct. 24	00:00	1.3	6	13	1.3	6	13
Oct. 24	06:00	1.3	6	13	1.7	7	15
Oct. 24	12:00	2.2	7	17	1.7	7	15
Oct. 24	18:00	2.2	7	17	2.2	7	17
Oct. 25	00:00	2.2	7	17	3.9	10	23
Oct. 25	06:00	2.2	7	17	3.9	10	23
Oct. 25	12:00	2.7	8	19	3.2	9	21

Oct. 25	18:00	2.7	8	19	3.2	9	21
Oct. 26	00:00	4.5	11	25	3.2	9	21
Oct. 26	06:00	3.9	10	23	2.2	7	17
Oct. 26	12:00	1.7	7	15	3.9	10	23
Oct. 26	15:00	1.0	5	13	1.7	7	15

4. RESULTS & DISCUSSION

From Table -5 above, it is clear that the main characteristics of the October 2019 Cyclone are as follows:

- Cyclone radius in mature phase is 270 km.
- Cyclone lifetime is 66 hours.
- Maximum wind speed is 25 knots (46 km/h).

These characteristics are within the limits of several Medicanes previously studied, for example, Cavicchia and von Storch (2011) [20], Tous and Romero (2013) [25], Nastos et al. (2015) [13] and also conform to the AU^2WS Medicane Scale shown in Table -4 above. Furthermore, the data in Table -5 showed that the significant wave height (Hs) inside the Cyclone in the mature phase is 4.5 m (corresponding to wind speed 25 knots).

It is noted that this Cyclone was slow during its movement as the average forward speed (V_F) was about 3.0 m/s. In addition, it was found that the average of Temperature, pressure at the center of Cyclone (p_0) and Precipitation are approximately 22°C, 755 mmHg and 6mm, respectively.

Table -6 showed that Hs in the region of Abu-Qir is 4.5 m (equal to the Medicane wave height), while Hs in the region of Port-Said is 3.9 m (slightly less than the Medicane wave height).

It is assumed that the most probable maximum wave height depends on the Number of waves (N) that are considered applicable to the significant wave height (i.e. H_S=4.5 m). Since the maximum wave conditions (H_{max}) occur at a distance equal to the radius of the maximum wind, the time it takes for the radius of the maximum wind to pass a certain point is (SPM, 1984) [27]:

$$t = \frac{R}{V_F} = \frac{270000}{3.0} = 90000 \text{ Sec} \qquad (1)$$

The number of waves (N) can be calculated as follows:

$$N = \frac{t}{T_S} = \frac{90000}{11} \approx 8181 \qquad (2)$$

Based on Rayleigh distribution, the most probable maximum wave height (H_{max}) can be calculated by using:

$$H_{max} = 0.707\ H_S\sqrt{\ln N} = 1.83\ H_S = 8.2 \text{ m} \qquad (3)$$

According to the metocean reports that were made for the regions of Abu-Qir and Port-Said offshore areas, the wave data used in the design of fixed offshore platforms in these regions are as follows in Table -7:

Table -7: Abu-Qir and Port-Said Offshore Platforms Criteria

Region	Platform Name	Location		Water Depth (m)	Wave Data	
		N	E		H_{max} (m)	Ts (S)
Abu-Qir	NAQ-PI	31 34	30 07	36.3	15.3	12.1
Port-Said	WEST AKHEN	31 54	31 54	80.0	17.0	13.2

From equation (3) it is clear the probable maximum wave height for this region due to the Cyclone (8.2 m) is much less than the maximum wave height values illustrated in Table -7 for the regions of Abu-Qir and Port-Said, where the fixed offshore platforms should not be evacuated during such a Cyclone.

5. CONCLUSIONS

In this research, a Cyclone of October 2019 was studied and its associated waves, as well as its effect on the existing fixed platforms located in the northern coast of Egypt. The study concluded the following:

- Satellite images showed that the Cyclone had a spiral shape and "Eye" in its center surrounded by a so-called "Eyewall". In addition, it was found that the characteristics of this Cyclone, such as the diameter "R" in the mature phase (in the range of 250∽270 km), maximum wind speed (about 25 knots) and its lifetime (about 2 days and 18 hours) were consistent in their results with previous studies of Mediterranean Cyclones. Accordingly, it can be said that this Cyclone is classified as a "Medicane".
- The significant wave height through the Cyclone was about 4.5 m which is equal to the significant wave height in the Abu Qir region, while it was 3.9 m in the Port Said region.
- It was found that the relationship between the significant wave height and the maximum wave height in the study area due to the hurricane is $H_{max} = 1.83\ H_S$.
- The maximum most probable wave height (H_{max}) in the offshore area of the northern coast of Egypt as a result of this Cyclone is about 8.2 m, which does not exceed H_{max} used in the design of fixed offshore platforms for this region (15.3 m in Abu Qir and 17 m in Port Said).

- There is no need to evacuate the fixed offshore platforms located in this area during the passage of such a Cyclone.

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