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Assessment of weather and climate variability over Western Harbor of Alexandria, Egypt

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ABSTRACT

The management of any harbor depends primarily on meteorological conditions. This study aimed to analyze the meteorological conditions over Western Harbor of Alexandria, using meteorological data recorded on an hourly basis from the automated weather station in the harbor from January 2007 to December 2018. The results revealed a general trend of a slight increase in the mean annual air temperature anomaly over the study period at a rate of 0.03°C/year. The mean annual sea-level pressure anomaly also showed an increasing trend at a rate of 0.011 h Pa/year. The dominant wind directions over the harbor were north-northwest during the study period. The lowest annual mean wind speed of 7 kt occurred in 2007, while the highest wind speed of 11 kt occurred in 2010. There was a trend of an increase in the mean annual wind speed anomaly at a rate of 0.12 kt/ year. In addition, there was a general trend of an increase in the mean annual relative humidity anomaly at a rate of 0.219 %/year. Four, six, eight, and ten extreme values were detected for air temperature, sea-level pressure, wind speed, and relative humidity, respectively. However, oceanographic parameters should also be examined to strengthen our findings. Nonetheless, mitigation and awareness plans should be prepared and implemented for the harbor.

INTRODUCTION

The climate system is a complicated system consisting of five major interacting components: the land surface, the biosphere, the atmosphere, the hydrosphere, and the cryosphere **(IPCC, 2001).** This system is influenced by various external forcing mechanisms, including different anthropogenic activities and solar radiation from the sun. There are two types of change in the climate system: climate change and climate variability: climate variability concerns changes that occur within smaller timeframes, such as a month, season or year, and climate change includes changes that occur over a longer period, typically over decades or longer **(IPCC, 2012 and Tonbol *et al*., 2018).**

Climate changes are evident in different kinds of phenomena globally, including higher air temperatures, more extensive dry regions, more frequent and intense extreme weather with vast changes in rainfall patterns, increased ocean acidity, warmer oceans, and accelerated rates of sea-level rise, with different rates of change among regions **(IPCC, 2007).** Depending on the land surface, evapotranspiration and the carbon cycle affect the climate in different ways **(Akinsanola & Ogunjobi, 2014).**

Knowledge of climate variability according to historical and long-term meteorological records at different temporal and spatial scales is important to understand the nature of different climate systems and their impact on the environment and society **(Oguntunde *et al*., 2012 and Tonbol *et al.,* 2018).** The climate of a location can be easily understood in terms of seasonal or annual averages in temperature and precipitation **(Akinsanola & Ogunjobi, 2014 and Tonbol *et al.,* 2018).**

In the twenty-first century, the Mediterranean region is one of the "hot spots" exposed to experience major climatic changes due to the global increase in greenhouse gas concentrations **(Marriotti, 2011 and Tonbol *et al.,* 2018).** The relationship between air temperature and the fluctuation of the sea surface temperature in the eastern Mediterranean was examined by **Repapis & Philandras (1988),** determining trends in variability over one hundred years. The same approach was taken by **Metaxas *et al*. (1991)** for the whole Mediterranean basin using a data series that extended from 1873 to 1989. Their results exhibited that trends and fluctuations in air temperature are highly affected by local differences and regional changes. Significant positive trends in Malta and Tripoli and a negative trend in Amman were observed in air temperature from eight meteorological stations in the Eastern Mediterranean basin (**Hasanean, 2001).** Air temperature data in Turkey during the period 1929–1999 was evaluated by (**Turkes *et al*., 2002)**, revealing spatiotemporal patterns of long-term trends, change points, and significant warming and cooling periods. In addition, **Maiyza *et al*. (2011)** detected a general decrease of 0.01°C/year in monthly air temperature anomalies from 1958 to 1990 in the southeastern Mediterranean Sea. **Tonbol and El-Geziry (2015)** concluded that variations in the daily sea surface temperature in the southeastern Mediterranean Sea are more related to variations in air temperature than wind speed **(Tonbol *et al.,* 2018)**.

Harbors play a substantial role in commerce, as promoters of economic growth, for global transportation, and for the development of global trade **(World Bank, 2010, Becker *et al*., 2012 and Tonbol *et al*., 2019).** Climate variability and change disproportionately affects harbors-based economies, depending on their geographic location and the adaptive capacities of the communities in which they are located **(Becker *et al*., 2012 and Tonbol *et al.,* 2019).** Climate variability and change can result in varying degrees of business interruption in harbors, including business closure in the most severe circumstances **(Chhetri *et al*., 2015).** Harbors must forestall the impacts of climate change and its effects, such as sea-level rise, increased flooding, high winds, storm surges, and more frequent extreme storm events to remain well organized **(Hallegatte *et al*., 2011, Asariotis & Benamara, 2012 and Tonbol *et al*., 2019).** As harbors are located on coastlines, they are vulnerable to changes in climate driving factors, such as air temperature, wind regimes, atmospheric pressure, and relative humidity. Harbor activities and operations are strongly dependent on these meteorological parameters **(Sánchez-Arcilla *et al*., 2016 and Tonbol *et al*., 2019).**

The current management protocols of harbors do not yet consider the impacts of potential climate change on their own operations **(Becker *et al*., 2012).** The available studies addressing the effects of climate change on harbors **(e.g., Hanson *et al*., 2011; Asariotis & Benamara, 2012** and **Sánchez-Arcilla *et al*., 2016)** are limited compared to the numerous assessments of climate change impacts on coastal areas **(Sierra *et al*., 2017).**

Therefore, this study aimed to describe the characteristics of air temperature, sea-level pressure, wind regime, and relative humidity in Western Harbor of Alexandria, Egypt; using meteorological data recorded on an hourly basis from the automated weather station in the harbor from January 2007 to December 2018.

MATERIALS AND METHODS

1. *Study area*

Western Harbor of Alexandria **(Fig. 1)** is the major trade port of the North Coast of Egypt and it is managed by the Alexandria Harbor Authority. It has 87 quays with a total length of more than 40000 m, and it is 7.4 km^2 in surface area, 7 km in length, 2 km in maximum width, and its depth ranges from 5.5–16 m. It lies between the longitudes of 29° 50.4′ and 29° 52.5′ E and latitudes of 31° 9.6′ and 31° 12′ N. The main entrance of the harbor is situated at the south-west side, between two beacons (Shiro & Awed). It has a width of 450 m with a water depth varying from 14.6 m in the middle of the outlet to about 10.2 m toward the edges.

2. *Data and methods of analysis*

The used meteorological datasets were recorded on an hourly basis at Western Harbor, Alexandria, along the Egyptian Mediterranean Sea Coast **(Fig. 1).** The datasets covers a period of 12 years from 1 January 2007 to 31 December 2018. It comprises air temperature, atmospheric pressure, relative humidity, and wind regime, including speed and direction. The datasets of the different parameters are complete over the 12 years with no missing data. The meteorological data were measured and recorded by the Egyptian Hydrographic Department in the Egyptian Navy using an automatic weather station in Ras El-Teen (station No. 62317; longitude: 29° 51' 49" E and latitude: 31° 11' 50" N. and height above sea level is 21.95 m).

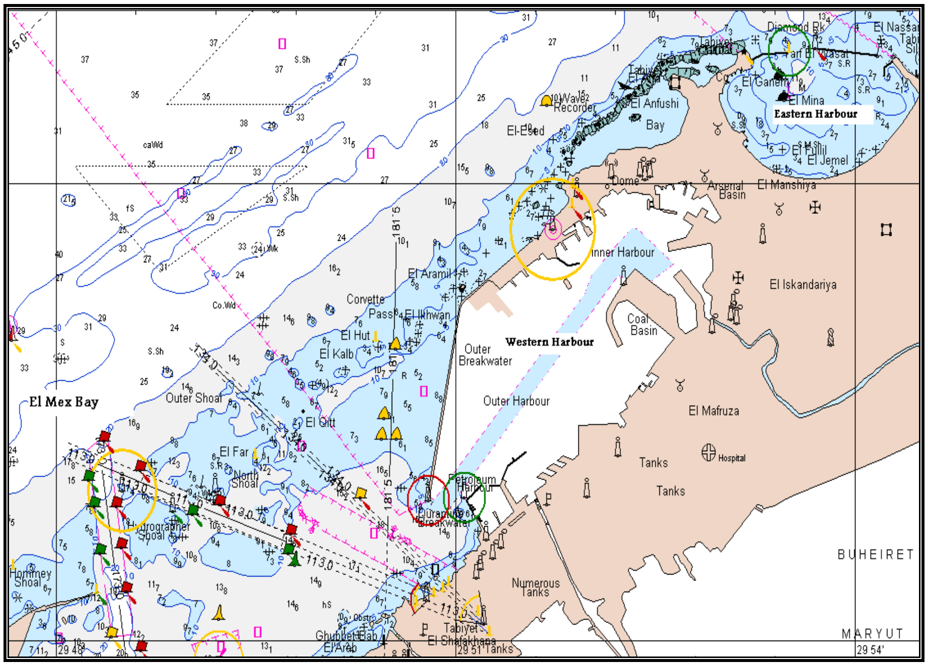

Fig. 1: A map of Egyptian Mediterranean Sea showing the location of Western Harbor and the automated weather station.

The minimum, maximum, mean values, monthly and annual means were calculated for each parameter to investigate seasonality and trends, respectively. Monthly and annual anomalies, which deviate from the monthly and annual means, respectively, were also calculated to detect any extreme event over Western Harbor during the period of investigation **(Tonbol *et al.*, 2019)**.

For example, the mean monthly air temperature over the period of investigation and the monthly mean air temperature for every month in the entire dataset were calculated. The deviation from the monthly mean was computed on a monthly basis to express the mean monthly air temperature anomaly (MMATA) **(Tonbol *et al.*, 2018)**, using an equation:

$$\Delta T = T - T_m \qquad (1)$$

Where,

ΔT is the MMATA (°C), T is the mean monthly air temperature (°C, mean for a specific month in a given year), and Tm is the monthly mean air temperature (°C, mean for a specific month over 2007–2018).

The statistical differences between the different years for each investigated parameter were tested using analysis of variance (ANOVA) in SPSS® with significance at $p < 0.05$.

RESULTS

1. Air temperature

The highest temperature recorded in the Alexandria Western Harbor data was 41°C during June 2010, and the lowest temperature was 7°C during February 2015 with an average temperature of 21.8°C **(Fig. 2)**. Air temperature fluctuated seasonally, recording a maximum average of 36.6°C during summer and a minimum average of 8.2°C during winter. The average maximum temperature was 34.7°C and the average minimum temperature was 14.7°C.

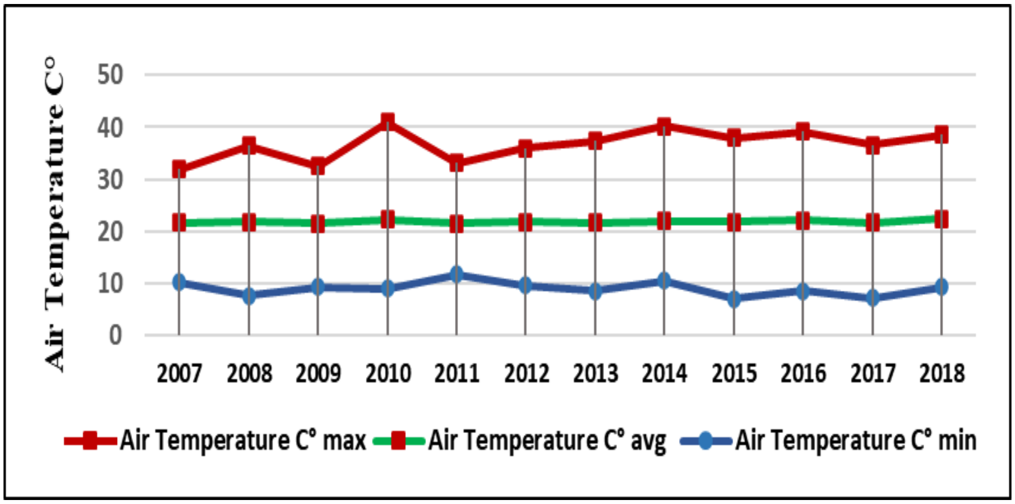

Fig. 2. Minimum, maximum, and mean annual air temperature over Western Harbor from 2007 to 2018.

The MMATA ranged between −1.89°C (November 2011) and 1.6°C (April 2016). The equation that expressed changes in the MMATA at Western Harbor is

$$\mathbf{Y = 0.002\ X - 0.15;\ r = 0.11}$$

This equation indicates that there was a very slight increase in the MMATA with a rate of 0.002°C/month. Four extremes were detected from the distribution of the MMATA **(Fig. 3)**, two of which were positive: February 2010 (1.48°C) and April 2016 (1.57°C), and the other two were negative: February 2008 (−1.53°C), November 2011 (−1.90°C).

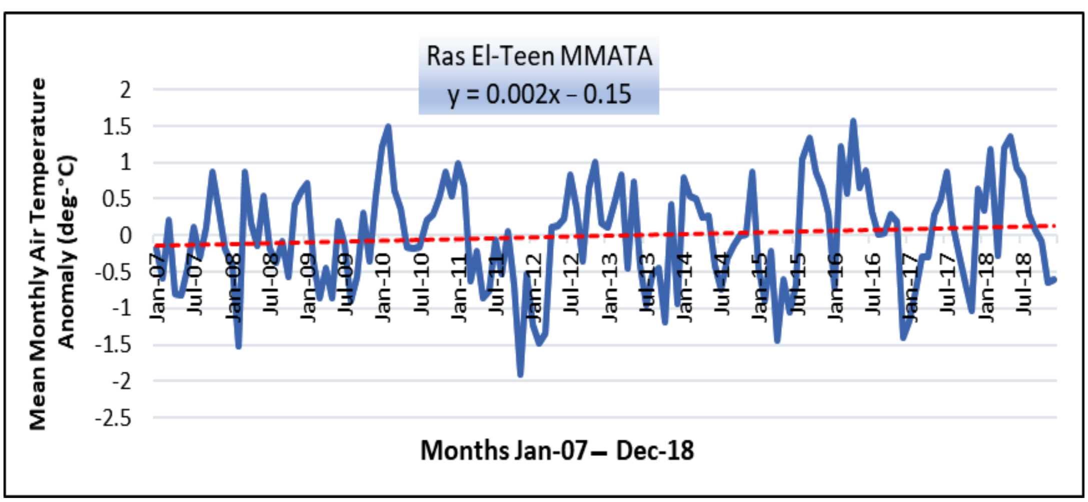

Fig. 3. Distribution and trend of the mean annual air temperature anomaly over Western Harbor, 2007–2018

For mean annual air temperature, 2011 had the lowest (21.5°C) among the 12 years of investigation and 2018 had the highest (22.4°C) mean annual air temperature. The mean annual air temperature anomaly (MAATA; **Fig. 4**) reflected a general increase in the MAATA over the period of the investigation that can be expressed by the equation

$$\mathbf{Y = 0.0322\ X - 0.20;\ r = 0.42}$$

This equation indicates that MAATA increased with a rate of 0.032°C/year. Two years, 2010 and 2018 were significantly different from all other years under investigation, according to the ANOVA **(Table 1)**.

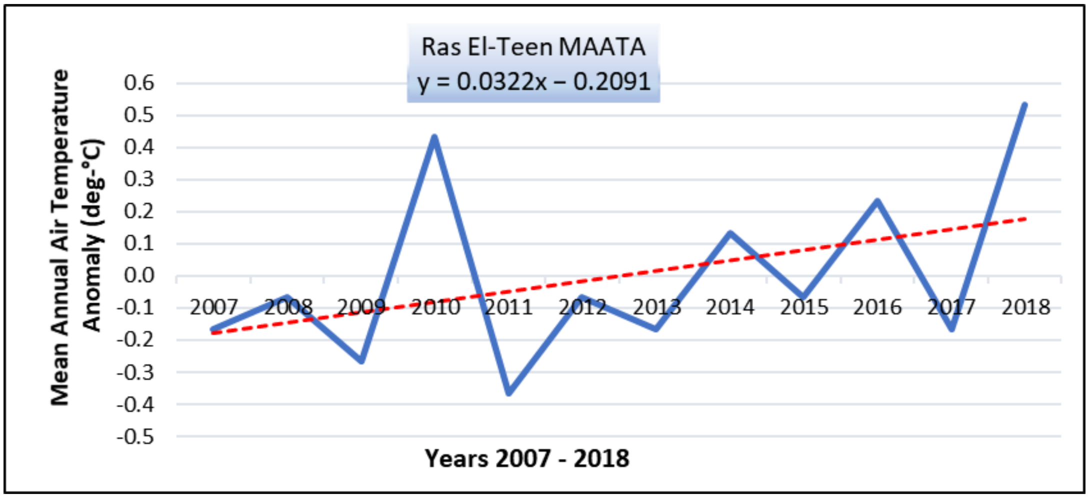

Fig. 4. Distribution and trends of the mean annual air temperature anomaly over Western Harbor, 2007–2018

Table 1. Statistical analysis of the annual air temperature over Western Harbor from January 2007 to December 2018

Year	**Air temperature (°C)**			
	Mean	Min	Max	Std.Dev.
2007	**21.7**	**10.2**	**32**	**4.8**
2008	**21.8**	**7.7**	**36.4**	**5.2**
2009	**21.6**	**9.3**	**32.6**	**4.6**
2010	**22.3**	**9**	**41**	**4.6**
2011	**21.5**	**11.8**	**33.2**	**4.6**
2012	**21.8**	**9.6**	**36**	**5.2**
2013	**21.7**	**8.6**	**37.4**	**4.6**
2014	**22**	**10.6**	**40.2**	**4.3**
2015	**21.8**	**7**	**38**	**5.1**
2016	**22.1**	**8.6**	**39.2**	**4.9**
2017	**21.7**	**7.2**	**36.6**	**4.9**
2018	**22.4**	**9.4**	**38.6**	**4.8**

2. Sea-level pressure:

The monthly mean sea-level pressure over Western Harbor from January 2007 to December 2018 ranged between 1005.9 hectopascals (hpa) (July 2012) and 1022.2 hPa (January 2007), with an overall average of 1013.4 hPa. The mean monthly sea-level pressure anomaly (MMSLPA) ranged from −3.4 hPa (March 2010) to 4.7 hPa (February 2008). Six extreme values were detected from, of which four were positive: 3.9 hPa (January 2007), 4.7 hPa (February 2008), 3.5 hPa (March 2011), and 3.3 hPa (March 2012; **Fig. 5**). The two negative extreme anomalies were −2.7 hPa in May 2007 and −3.4 hPa in March 2008. The linear trend of the MMSLPA reflected a general increase with a rate of 0.001 hPa/month and can be mathematically expressed by the equation

$$y = 0.001x - 0.0732;\ r = 0.42$$

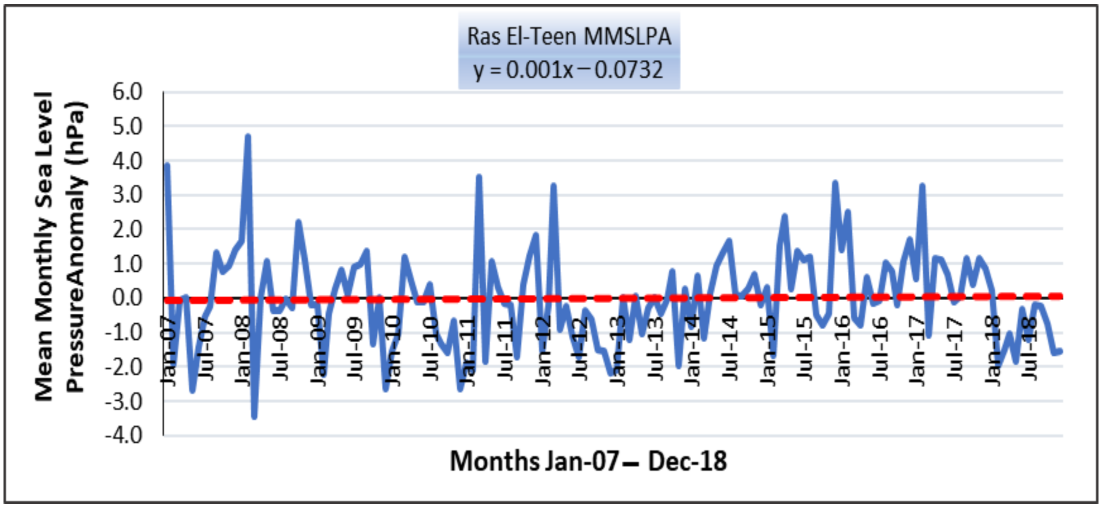

Fig. 5. Distribution and trend of the mean monthly sea-level pressure anomaly over Western Harbor, 2007–2017

The annual normal values of atmospheric pressure in this study were different between years. The recorded atmospheric pressure values from 2007–2018 indicated that the highest value of 1032.3 hpa was recorded in 2007, having a mean annual atmospheric pressure of 1013.5 hpa. However, the lowest atmospheric pressure value of 998.2 hpa was recorded in 2018 with an annual mean record of 1012.4 hpa **(Fig. 6)**.

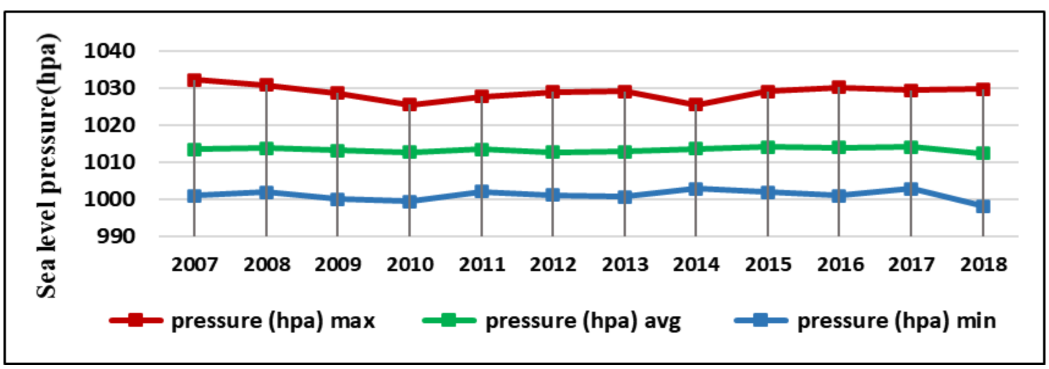

Fig. 6. Minimum, maximum, and mean annual sea-level pressure over Western Harbor from 2007 to 2018.

The minimum annual mean sea-level pressure was 1012.4 hPa in 2018, and the maximum was 1014.2 hPa in 2017, with an average of 1013.4 hPa. However, the mean annual sea-level pressure anomaly (MASLPA) ranged between −0.98 hPa in 2018 and 0.75 hPa in 2017 **(Fig. 7)**.

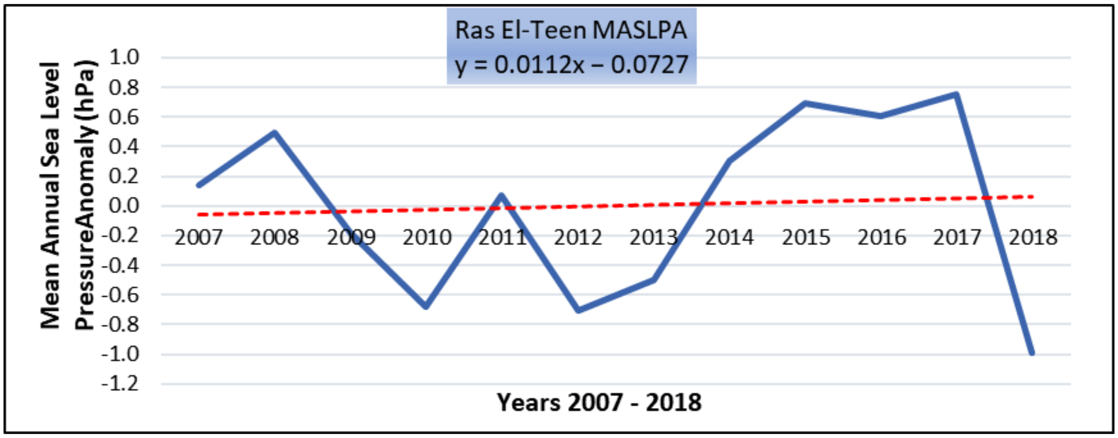

Fig. 7. Distribution and trends of the mean annual sea-level pressure anomaly over Western Harbor, 2007–2018.

The MASLPA also showed a general trend of increase, which can be mathematically expressed by the equation

$$y = 0.011x - 0.0727; \ r = 0.07$$

The rate of increase in MASLPA was 0.11 hPa/year. The ANOVA showed that in 2018 the recorded sea-level pressure was significantly different to that of the other 11 years **(Table 3)**.

Table 2. Statistical analysis of the annual sea level pressure over Western Harbor from January 2007 to December 2018

Year	Sea level pressure (hPa)			
	Mean	Min	Max	Std.Dev.
2007	1013.5	1001.1	1032.3	5.4
2008	1013.9	1002.0	1030.8	5.2
2009	1013.2	1000.1	1028.7	4.3
2010	1012.7	999.6	1025.6	4.4
2011	1013.5	1002.1	1027.8	4.9
2012	1012.7	1001.2	1028.9	4.9
2013	1012.9	1000.7	1029.2	4.5
2014	1013.7	1002.9	1025.5	4.3
2015	1014.1	1002.0	1029.2	4.8
2016	1014.0	1001.1	1030.2	5.0
2017	1014.2	1002.9	1029.5	5.0
2018	1012.4	998.2	1029.8	4.8

3. Wind regime

The dominant direction of wind blowing over the harbor during the period of investigation was north-northwest (NNW).

The monthly mean wind speed varied between 5.3 kt (August 2007) and 14.2 kt (January 2018), with an overall mean wind speed of 10.1 kt. The mean monthly wind speed anomaly (MMWSA) varied between −5.8 kt in July 2007 and 4.1 kt in January 2018 **(Fig. 8)**. This increase in MMWSA had a rate of 0.01 kt/month and can be mathematically expressed by the equation

$$y = 0.0101x - 0.7275;\ r = 0.25$$

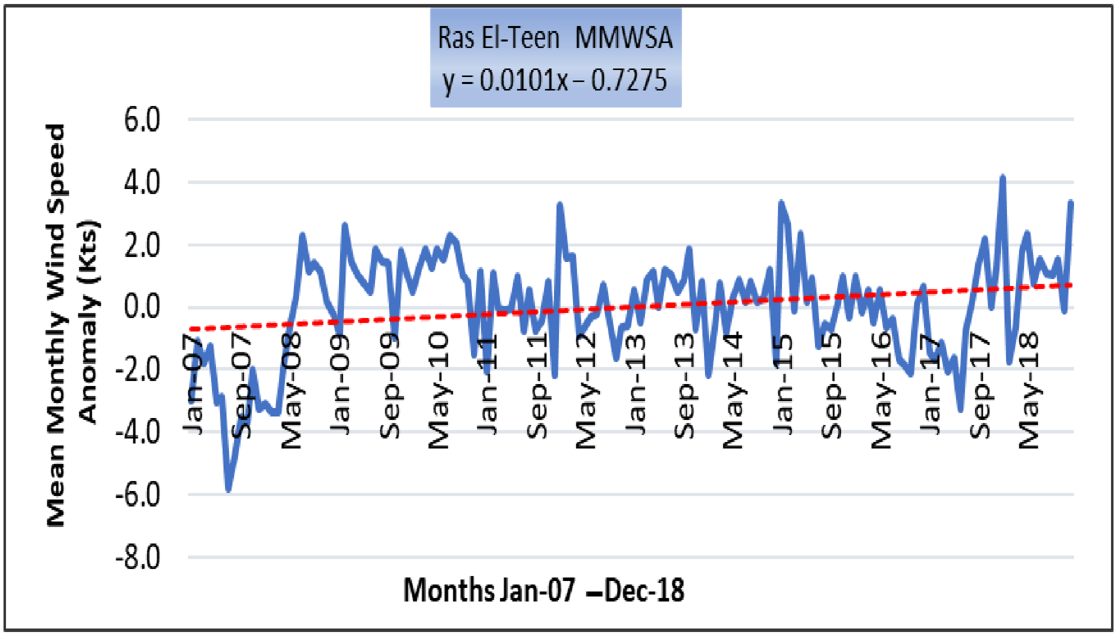

Fig. 8. Distribution and trend of the mean monthly wind speed anomaly over Western Harbor, 2007–2018.

From the MMWSA distribution, eight extremes were observed, four of which were positive. The positive MMWSA extremes were 3.3 kt (January 2012), 3.3 kt (January 2015), 4.1 kt (January 2018), and 3.3 kt (December 2018). The negative extremes were −5.8 kt (July 2007), −4.8 kt (Augustus 2007), −3.7 kt (October 2007), and − 3.4 kt (February 2008).

The mean annual wind speed was lowest (7 kt) in 2007 and highest (11.4 kt) in 2018. The mean annual wind speed anomaly **(Fig. 9)** ranged from −3.03 kt (2007) to 1.28 kt (2018). It had an increasing trend with a rate of 0.125 kt/year. It can be expressed as

$$y = 0.1257x - 0.8168;\ r = 0.39$$

Results in **Table (4)** summarize the statistical analysis of the annual wind speed over Western Harbor from January 2007 to December 2018.

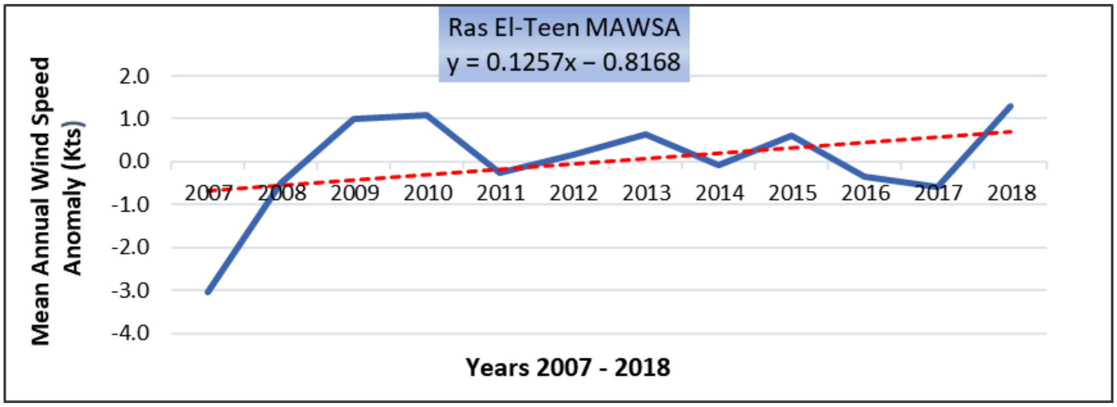

Fig. 9. Distribution and trend of the mean annual wind speed anomaly over Western Harbor, 2007–2018

Table 3. Statistical analysis of the annual wind speed over Western Harbor from January 2007 to December 2018

Year	Wind speed (Kts)			
	Mean	Min	Max	Std.Dev.
2007	7.0	0.0	27	4.2
2008	9.6	0.0	34	4.9
2009	11.1	0.0	40	5.5
2010	11.2	0.0	46	5.8
2011	9.8	0.0	35	5.1
2012	10.2	0.0	34	5.5
2013	10.7	0.0	39	5.1
2014	10.0	0.0	29	4.3
2015	10.7	0.0	38	5.2
2016	9.7	0.0	38	5.4
2017	9.5	0.0	36	4.8
2018	11.4	0.0	38	4.8

4. Wind pattern

The average wind speed was 10.1 kt while the maximum was 46 kt in 2010 and 30.7% of the blowing wind was NNW (Figs. 10 and 11). The frequency of calm winds from 0 to less than 0.9 kt speed was 1.1% and from 11.08 to 17.11 kt was 33.2%, with extreme winds occurring in storms more than 21.58 kt being 2.9 % during the pass of depressions (Table 5).

A significantly different wind speed was recorded between years excluding 2007, 2008, and 2017.

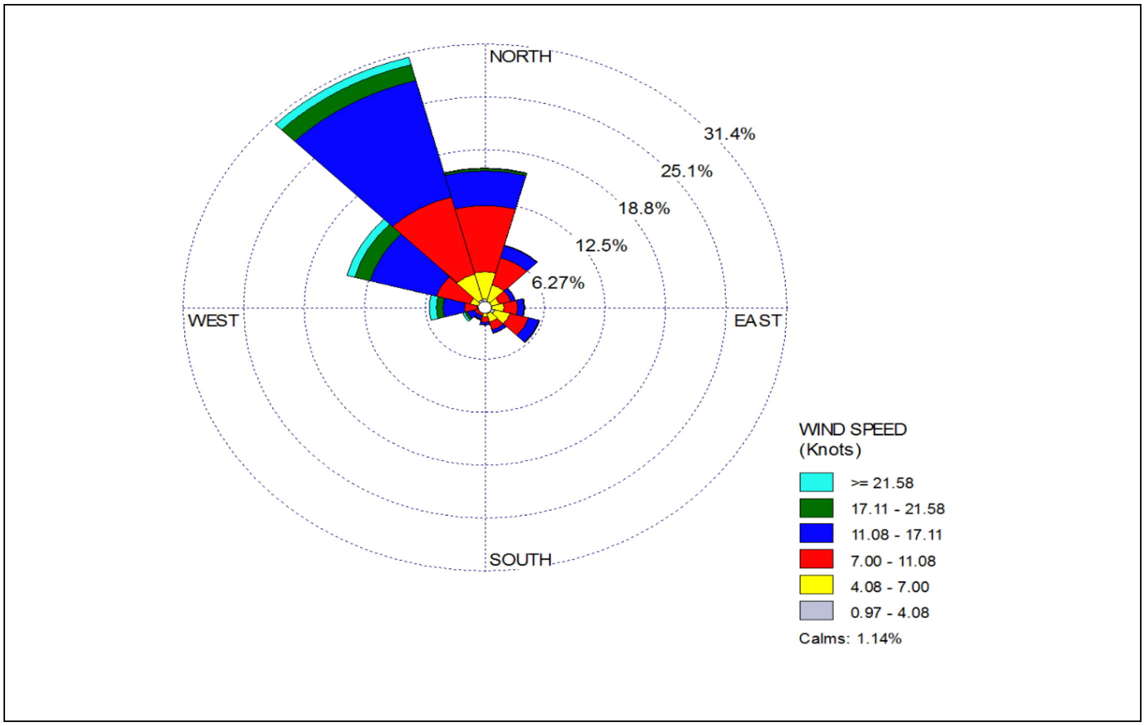

Fig. 10. Wind rose over Western Harbor during the study period

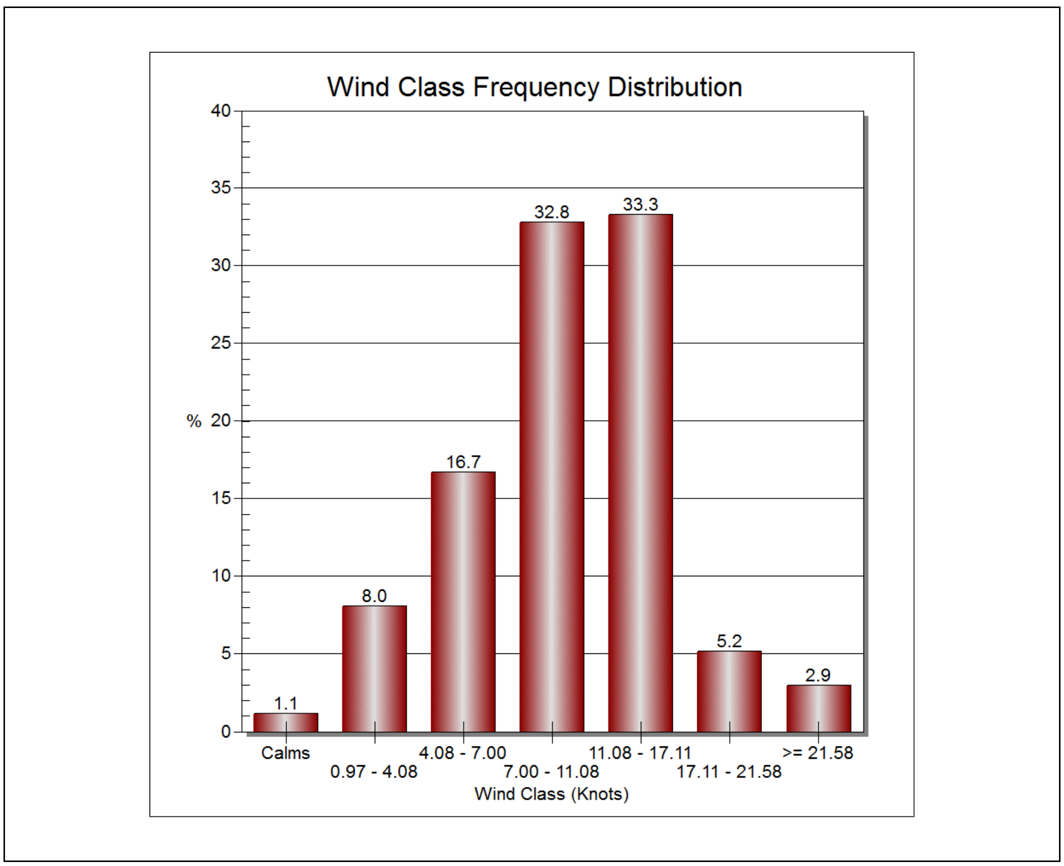

Fig. 11 Wind speed frequency distribution during the study period

Table 4. Wind speed and direction frequency over Western Harbor from January 2007 to December 2018

Directions/ Wind Classes (Knots)	1–4	4–7	7–11	11–17	17.–21.58	>=21.58	Total (%)
N	1.09	3.23	7.82	4.11	0.27	0.08	**16.60**
NNE	0.83	2.02	3.33	1.48	0.06	0.01	**7.72**
ENE	0.56	1.06	1.23	0.48	0.03	0.01	**3.37**
E	0.78	1.28	1.41	0.67	0.06	0.00	**4.20**
ESE	1.16	1.60	1.99	1.10	0.08	0.01	**5.95**
SSE	0.88	1.00	0.95	0.40	0.04	0.00	**3.27**
S	0.54	0.70	0.62	0.28	0.05	0.01	**2.20**
SSW	0.22	0.39	0.50	0.41	0.09	0.07	**1.67**
WSW	0.22	0.38	0.61	0.77	0.24	0.24	**2.47**
W	0.27	0.64	1.30	2.21	0.68	0.75	**5.85**
WNW	0.45	1.22	3.58	7.09	1.66	0.85	**14.85**
NNW	1.04	3.14	9.43	14.27	1.92	0.91	**30.71**
Sub-Total	8.03	16.68	32.78	33.27	5.16	2.93	**98.86**
Calms							**1.14**
Missing							**0.0**
Total							**100**

5. Relative humidity

The mean monthly relative humidity over Western Harbor ranged between 57.3% (January 2008) and 77.6% (July 2009), with an overall mean of 68.7% during the period of investigation.

The annual normal values of the relative humidity in this study from 2007–2018 indicate that the highest value of 99% was recorded in 2008–2014 with an annual mean relative humidity of 64.9%. However, the lowest value of 11% was recorded in 2009 (Fig. 12).

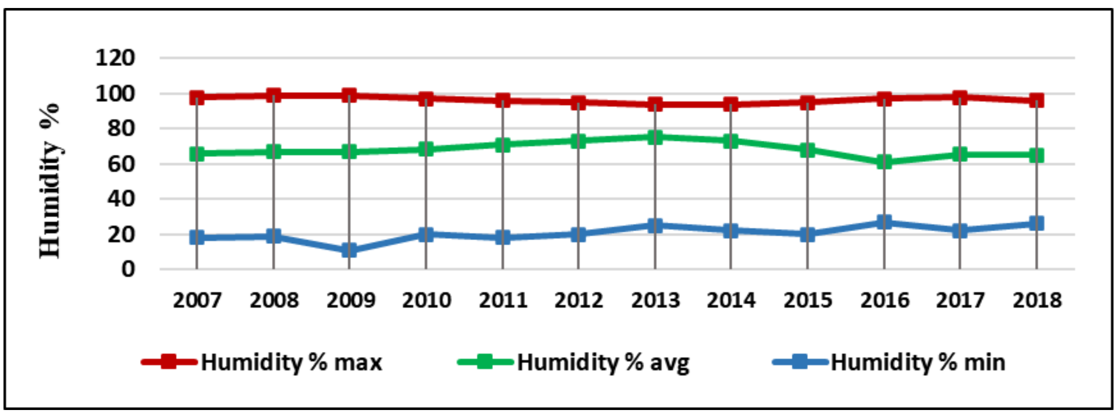

Fig. 12. Minimum, maximum, and mean annual wind speed over Western Harbor from 2007 to 2018.

The mean monthly relative humidity anomaly (MMRHA; Fig.13) ranged from −8.4% (January 2008) to 6.9% (January 2014). The MMRHA had an increasing trend over the period of investigation, with a rate of 0.0191%/month. This linear trend can be mathematically expressed by the equation

$$y = 0.0191x - 1.0812;\ r = 0.28$$

From the MMRHA distribution, 10 extreme values were detected, five of which were positive. The positive extremes were observed in October 2007 (7.4%), October 2010 (5.7%), October 2012 (7.7%), November 2013 (5.4%), and January 2014 (6.9%).

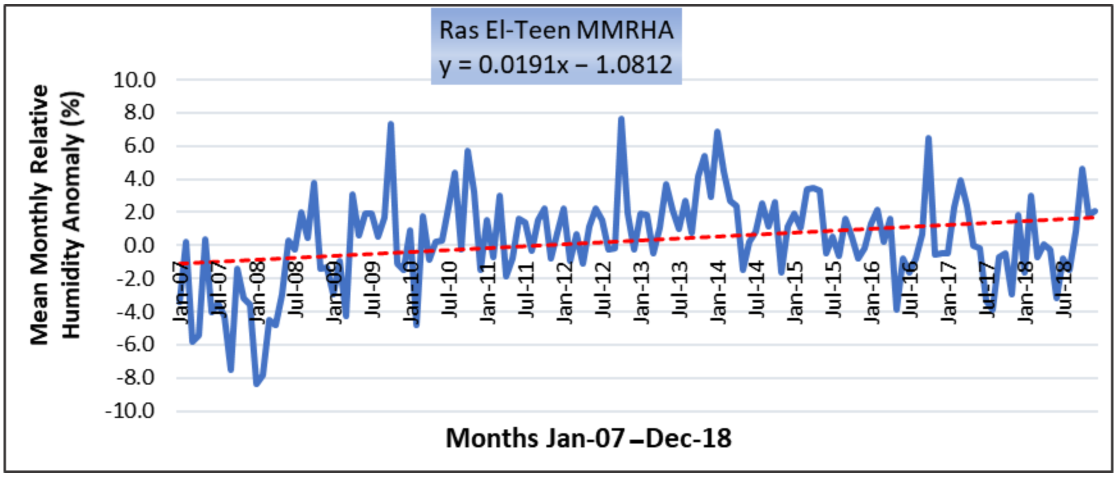

Fig. 13. Distribution and trend of the mean monthly relative humidity anomaly over Western Harbor, 2007–2018.

The negative extremes were observed in March 2007 (5.8%), April 2007 (5.5%), September 2007 (7.5%), January 2008 (8.4%), and February 2008 (7.8%).

The year 2007 had the lowest annual mean relative humidity (65%), while 2013 had the highest (71%). However, the mean annual relative humidity anomaly (MARHA) varied between −3.9% in 2007 and 1.9% in 2013 (Fig. 14). The increasing linear trend of the MARHA can be expressed by the equation

$$y = 0.219x - 1.4237;\ r = 0.48$$

The MARHA had a rate of 0.219%/year from January 2007 to December 2018. The years 2007 and 2013 were the only two years showing a total significance in the recorded relative humidity with respect to other years (Table 6).

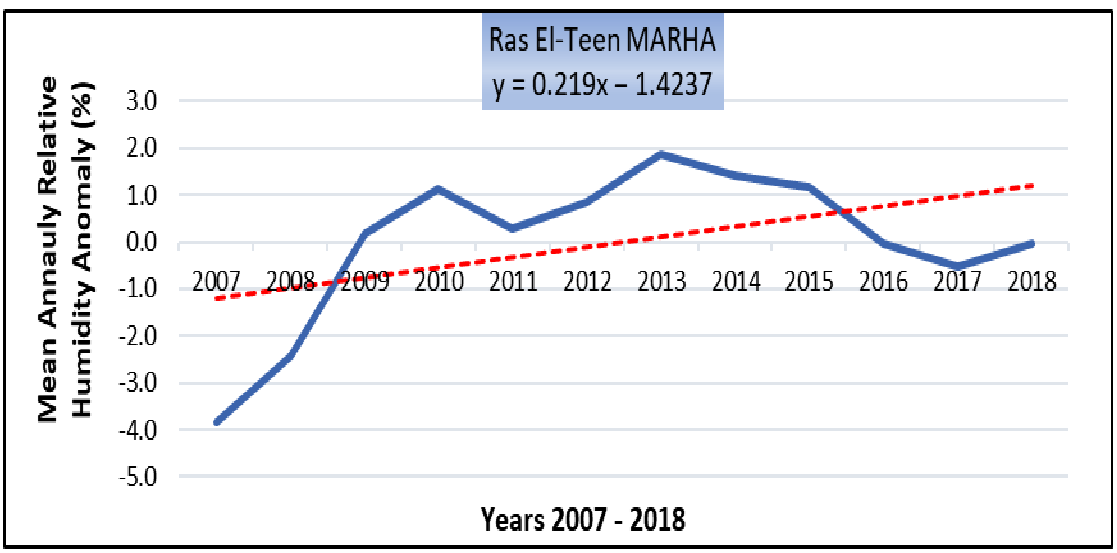

Fig. 14. Distribution and trend of the mean annual relative humidity anomaly over Western Harbor, 2007–2018

Table 5. Statistical analysis of the annual relative humidity over Western Harbor from January 2007 to December 2018

Year	Relative humidity (%)			
	Mean	**Min**	**Max**	**Std.Dev.**
2007	**65**	**30**	**89**	**8.3**
2008	**66**	**11**	**99**	**11.3**
2009	**69**	**16**	**97**	**11.7**
2010	**70**	**15**	**98**	**11.8**
2011	**69**	**20**	**96**	**9.5**
2012	**70**	**26**	**98**	**10**
2013	**71**	**20**	**96**	**10.7**
2014	**70**	**18**	**99**	**9.8**
2015	**70**	**20**	**96**	**9.7**
2016	**69**	**21**	**99**	**10.1**
2017	**68**	**22**	**97**	**10**
2018	**69**	**21**	**98**	**10.1**

DISCUSSION

The economy relies on maritime transportation and sea-going trade to a considerable extent. Ports and the shipping industry are affected by climate variability. However, globally, many ports are still unaware of the likely pressures of climate variability and change, or they are slow to implement suitable adaptation actions. The effects of climate variability and change on harbors include sea-level rise, wind and storm regimes, extremely hot days, change in precipitation patterns, and flooding, effecting maritime operations, and activities **(Tonbol *et al*., 2019)**. This paper highlights the changes in meteorological conditions over the most important Egyptian port along the Mediterranean Coast: Western Harbor. According to our knowledge, no available literature has been conducted on this topic for the Western Harbor. Varieties within the examined meteorological parameters play a vital part in deciding the impact of climate variability within the region of the harbor since its shoreline configuration and its services are in dynamic balance with the meteo-oceanographic patterns.

The current work is based on hourly data records of four meteorological parameters including air temperature, sea-level pressure, wind regime, and relative humidity from the automated weather station at Western Harbor: The dataset covers a period of 12 years (January 2007 to December 2018) with no missed data. The anomalies, which are deviations from the mean, were calculated for each parameter, to examine trends and detect any extreme values according **Tonbol *et al.* (2019)**. Anomalies permit the elimination of external effects on the examined parameter and, therefore, lead to more convenient and reasonable conclusions on trends and behavior of change **(Tonbol *et al.* 2019)**.

Over the period of examination, the detected temperature appeared slight patterns of increase (0.002°C/month) and (0.03°C/year). The observed increase in air temperature can influence, on a regional basis, the calculated mean sea level and the rate of sea-level rise at the harbor, and it can affect the storm development process **(Tonbol *et al*., 2019).**

The maximum air temperature (41°C) was recorded during June 2010, and the minimum value 7°C was recorded during February 2015 with an average temperature of 21.8°C. Along the Mediterranean Sea coast, seasonal variations in air temperate are related to the prevailing climate of the Mediterranean Sea, which is affected by both subtropical and mid-latitude weather systems. According to the Egyptian Metrological Organization records for the last century, the maximum and minimum values of temperature reach 38°C in summer and 8°C in winter **(Hazem, 1999).** The values we found were more extreme than this.

The sea-level pressure over Western Harbor tends to be ordinarily conveyed with regard to the detected air temperature. In any case, the sea-level pressure tended also to appear an expanding slant over the consider period on both monthly and annual basis with rates of 0.001 hPa/month and 0.011 hPa/year, respectively. The influence of sea-level pressure change is watched in changes in sea levels in the region of the harbor, and it is likely that more changes are expected in the future.

The wind regime over the Egyptian Mediterranean Coast is related to the prevailing wind of this region. The wind speed and direction varied diurnally and seasonally. The present study showed that the wind direction and frequency distribution of the wind class of the study area depended on variations in atmospheric pressure. The predominant wind in the study area was NNW, and the average wind speed was 11–17 kt for 42.1% of the total wind. Extreme winds of >22 kt occurred during storms in a north to northeast and southerly direction. This variation in wind regime was controlled by the Azores anticyclone extension over the Libyan Desert and the North Atlantic depression entering the eastern Mediterranean area associated with cold Atlantic air masses. This cold air meets the warm and moist air of the Mediterranean area. Consequently, vertical instability and moving atmospheric perturbations, associated with meteorological fronts are generated. The traveling depressions, when associated with ridges of high pressure over the northwestern Libyan Desert, generate high waves and cause showers, thunderstorms, and rising sand or sandstorms, as mentioned by **Elbessa (2011).** The wind speed at Western Harbor tended to increase with time at rates of 0.01 kt/month and 0.12 kt/year. Any change in the wind speed and direction could affect the harbor's structural safety and functionality and impact on its services, e.g., ship berthing, goods loading and unloading, and crane operations **(Tonbol *et al.* 2019)**.

Our results revealed a general increase in the trends of relative humidity on both a monthly and annual basis: 0.01%/month and 0.219%/year with a minimum value of 11% in 2008 and a maximum value of 99% in 2014.

In conclusion, the location of the western port geographically protects the port from the prevailing direction of winds (north or northwest) and generally affects the movement of water, such as waves, surface currents, and sea-level rise. The sheltered location of the harbor, which is secured by a six water vents (ash-toms) breakwater, seems to provide stable metrological conditions over Western Harbor, except when air depressions pass, where the wind speed increases by more than 22 kt, as this leads to the closure of the port and the suspension of maritime navigation in the port. Our results could contribute to informing safe maritime operations and activities over time. However, the oceanographic parameters of sea surface temperature, sea-level, surface currents, and waves should also be examined to confirm this stability.

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ARABIC SUMMARY

تقييم تقلبات الطقس والمناخ عبر الميناء الغربي بالإسكندرية، مصر

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تعتمد إدارة أي ميناء بشكل أساسي على ظروف الأرصاد الجوية. هدفت هذه الدراسة إلى تحليل ظروف الأرصاد الجوية على الميناء الغربي بالإسكندرية، باستخدام بيانات الأرصاد الجوية المسجلة على أساس كل ساعة من محطة الأرصاد الجوية الآلية في الميناء من يناير 2007 إلى ديسمبر 2018.

كشفت النتائج عن اتجاه عام لزيادة طفيفة في متوسط شذوذ درجة حرارة الهواء السنوي خلال فترة الدراسة بمعدل 0.03 درجة مئوية / سنة. كما أظهر متوسط شذوذ ضغط مستوى سطح البحر السنوي اتجاهًا متزايدًا بمعدل 0.011 هبأ / هكتوباسكال. كانت اتجاهات الرياح السائدة فوق الميناء شمال- شمال غرب البلاد خلال فترة الدراسة. سجلت الدراسه أدنى متوسط سرعة الرياح السنوية 7 عقده في عام 2007م، بينما سجلت أعلى سرعة الرياح 11 عقده في عام 2010م. وكان هناك اتجاه لزيادة متوسط سرعة الرياح غير العادية بمعدل 0.12 عقده / سنة. بالإضافة إلى ذلك ، كان هناك اتجاه عام لزيادة متوسط شذوذ الرطوبة النسبية السنوية بمعدل 0.219٪ / سنة. تم الكشف عن أربع، وست، وثماني، وعشر قيم متطرفة لدرجة حرارة الهواء، وضغط مستوى سطح البحر، وسرعة الرياح،

والرطوبة النسبية، على التوالي. ومع ذلك ، يجب أيضًا فحص المعلمات الأوقيانوغرافية لتعزيز هذه النتائج. ومع ذلك، ينبغي إعداد خطط التخفيف والتوعية وتنفيذها للميناء الغربي بالإسكندرية، مصر.