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CURRENTS IN FRONT OF MANZALAH LAKE, EGYPT

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ABSTRACT

The coastal area in front of Nile Delta is considered one of the most interesting natural laboratories not only because of its coastal processes and evolution of erosion and accretion, but also because of its economic importance related to Egyptian natural resources. Knowledge of coastal water circulation is one of the basic tools useful in the management of fisheries as well as in oil and gas resources development.

The present study is concerned with the analyses of current and meteorological measurements in the coastal water in front of Lake Manzalah between Damietta and Port Said.

The results showed that the currents are strongly influenced by wind, which indicates continuous changes with time. The Current direction frequencies indicated that in Shallow Water, ESE and WNW currents are the most frequent with frequencies 52% and 13% respectively. The first direction represents the strongest current with a maximum speed of 0.87 m/sec. The mean current speed varies between 0.15 m/sec at surface and 0.09 m/sec near the bottom.

In Deep Water, the maximum recorded current speed was 0.50 m/sec directed towards ESE. The majority current frequencies were 29% and 14% towards SE and NW respectively. Weak currents showed great variability in direction, and the diurnal variations in the current speed and direction are often observed.

INTRODUCTION

The coastal area in front of Nile Delta is considered one of the most interesting natural laboratories not only because of its coastal processes and evolution of erosion and accretion, but also because of its economic importance related to Egyptian natural resources. Knowledge of coastal water circulation is one of the basic tools useful in the management of fisheries as well as in oil and gas resources development. Spills of oil and other materials from offshore drilling and oil transport activities may occur and significantly affect the environment; therefore transportation of such pollutants becomes very important..Direct current measurements in the southeastern Mediterranean off the Egyptian coast were scare. Few current measurements using Ekman current-meter between Abu-Qir Bay and Port Said were observed during 1969 (Hassan, 1969). Murray (1980) studied the current patterns east of Damietta promontory (10-25 m depth). Gerges (1981) studied the monthly patterns of surface currents obtained by averaging all current measurements carried out in each one-degree square along the Egyptian coast over a period of 50 years, up to the early Seventies. Based on current measurements carried out in 1988, Said (1994) studied the variation of currents off the Nile Delta coast. Gewilli (1994) studied the long shore current for ten years (1982-1991) where the observations were taken at both sides of Rosetta mouth, Burullus outlet and Damietta mouth along the Nile Delta coast. Abdalla (2003) studied the coastal processes along Damietta promontory.

The study area lies between latitude 31° N and 32° N and longitude 32° E and 32° 30` E as shown in Fig. 1.

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The Objective of the present study is the evaluation of the current variations in shallow and deep waters in front of Lake Manzalah between Damietta and Port Said and the effect of meteorological conditions on it.

REVIEW OF PREVIOUS STUDIES

a- Beyond the Breaker Zone:

Current observations in front the Nile Delta at depths between 5 and 15 meters have been studied by El Gindy et al.(1984). They found diverged surface currents in the vicinity of Damietta mouth and two cyclonic gyres in front of Gamasa and El-Gamil outlets. The surface currents off the Egyptian coast have magnitudes of 0.25-0.50 m/sec, but the velocities and direction are strongly influenced by the wind (Sharaf El Din, 1973). Northeast of Damietta, strong bottom currents created a field of activity migrating sand ridge at depths 25-60 m (Coleman *et al.*, 1980, Murray *et al.*, 1980).

b- From Breaker Zone Up to 6 m Depth:

The movement of the near shore water is generally more complicated than that of the offshore one. It depends in a complex fashion, on the bottom and coast configurations, the wind and the horizontal and vertical density gradients. The Coastal Research Institute, measured currents from the breaker zone up to 6 meter depth. These observations showed that the currents inside 6 meter depth vary considerably in magnitude from year to year owing presumably to the importance of localized wind in their generation, (UNDP/UNESCO, 1973). Manohar (1976) studied the dynamic factors affecting the Nile Delta coasts. He confirmed that, from the breaker zone up to 6 meter depth, the velocities are high as 0.6 m/sec.

c- Littoral Current:

The long shore currents are produced in the breaker zone due to the momentum of the wave breaking at an angle with shoreline. Westward directed currents are more important along the western flanks of the Rosetta and Damietta promontories due to the local SW-NE shoreline orientations (Fanos *et al.*, 1991). Gewilli (1994) studied the longshore current from ten years (1982-1991) where the observations were taken at both sides of Rosetta mouth, Burullus outlet and Damietta mouth along the Nile Delta coast. He found that, the predominant current directions are toward east except on west side of Rosetta mouth where the current is from N to S. The maximum current reached about 0.8 m/sec at Rosetta, 0.95 m/sec at Burullus and 0.91 m/sec at both sides of Damietta mouth, while the average velocity was found to be 0.37, 0.47 and 0.25 m/sec at the three regions respectively.

DATA DESCRIPTION

The current and meteorological data used in the present study have been collected by Fugro Global Environmental and Ocean Sciences (Fugro GEOS), during the period from February 1999 to January 2000. Fig.(1) shows the locations of the measurement stations, while Table (1) and Fig. (2) show the inventory of Data Collection and the bar chart of the valid data return for each instrument.

a- Meteorological Measurements:

A meteorological station was installed on the Wakar Platform on the walkway leading to the flare off boom 28.75 m. above MSL at 31° 43.00` N and 032° 24.50` E. The measurement system consisted of a self-contained Aanderaa Meteorological Station, comprising modular sensors mounted on a 2 m. mast and a multi-channel controller unit fitted with a DSU (Data Storage Unit). Sensors were fitted to measure wind speed, wind direction, atmospheric pressure, air temperature, relative humidity and rainfall. Ten-minute mean wind speed and direction; 10 minute cumulative rainfall and instantaneous air temperature, atmospheric pressure and relative humidity were recorded. The complete mooring configuration of the meteorological station is shown in Fig. (3).

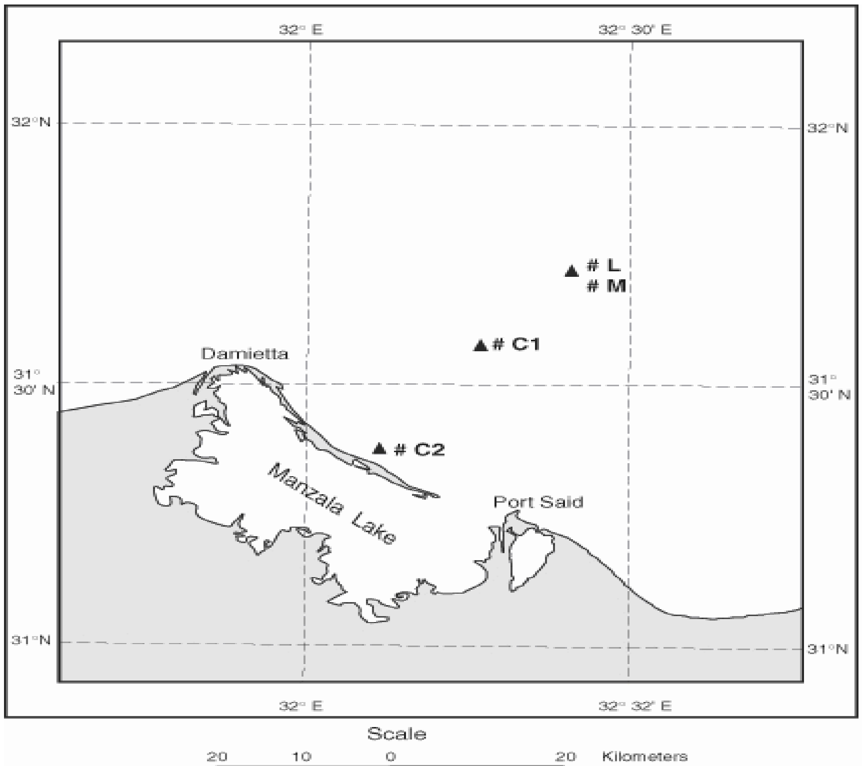


Fig. 1: Chart of the investigated area and the locations of the measurement stations

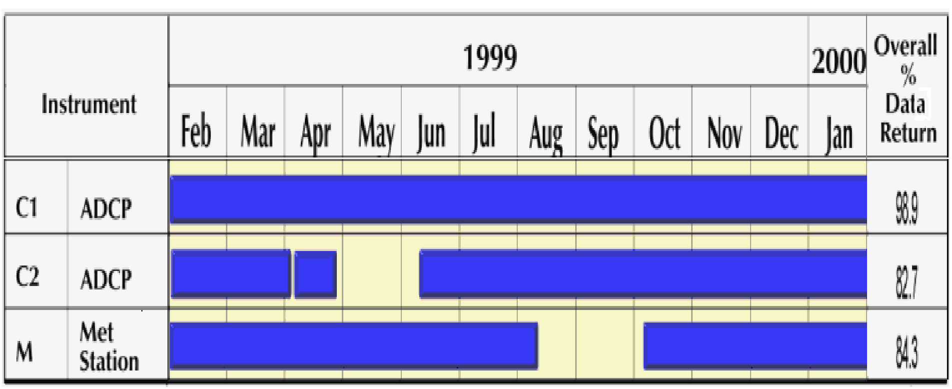


Fig. 2: The bar chart of the valid data return for each instrument.

Table 1: Inventory of data collection

Type of Data	Location			Instrument Type	Period of Record	Time interval of Recording	Comments
	Actual Position		Water Depth (m)				
	Lat (N)	Long (E)					
Deep Current (C1)	31° 34.90`	032° 15.93`	29	Workhorse Acoustic Doppler Current Profiler (WHADCP)	3-Feb-1999 to 31-Jan-2000	10 min sampling	ADCP stopped collecting data due to battery failure on 5 December 1999
Shallow Current (C2)	31° 22.98`	032° 07.00`	8				Mooring was trawled on 24 April 1999, replaced with another one
Meteorology (M)	31° 43.00`	032° 24.50`	45	Aanderaa Met. Station		Instantaneous every 10 min	Due to technical problem with the data storage unit (DSU) all data were lost for 10-Aug-1999 to 06-Oct-1999

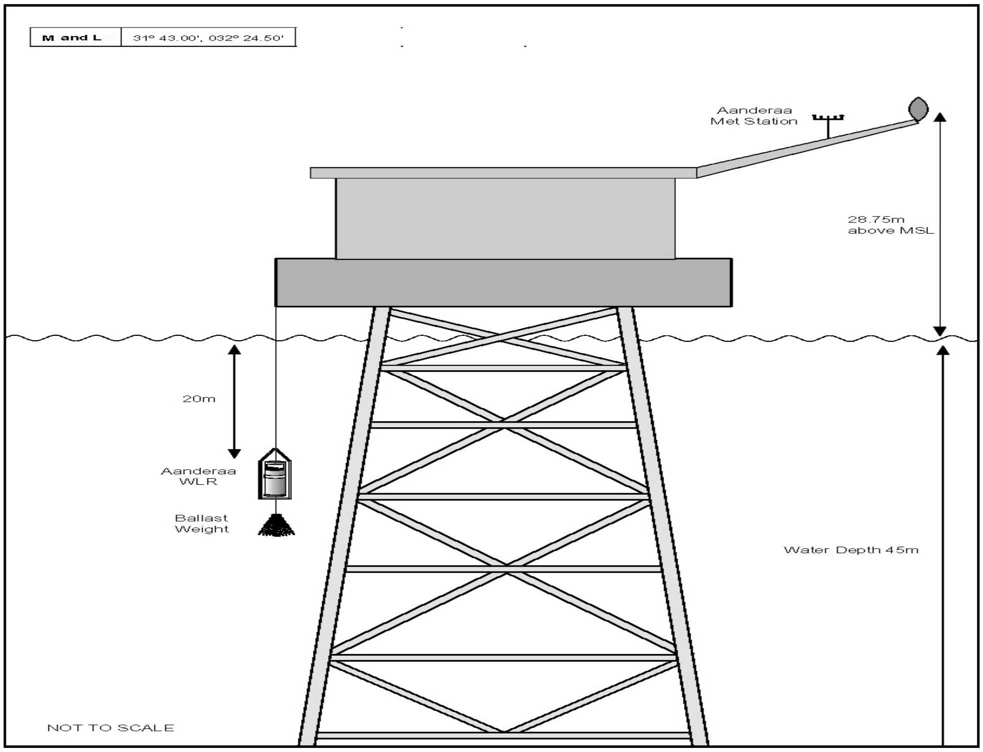


Fig. 3: Configuration of meteorological and sea

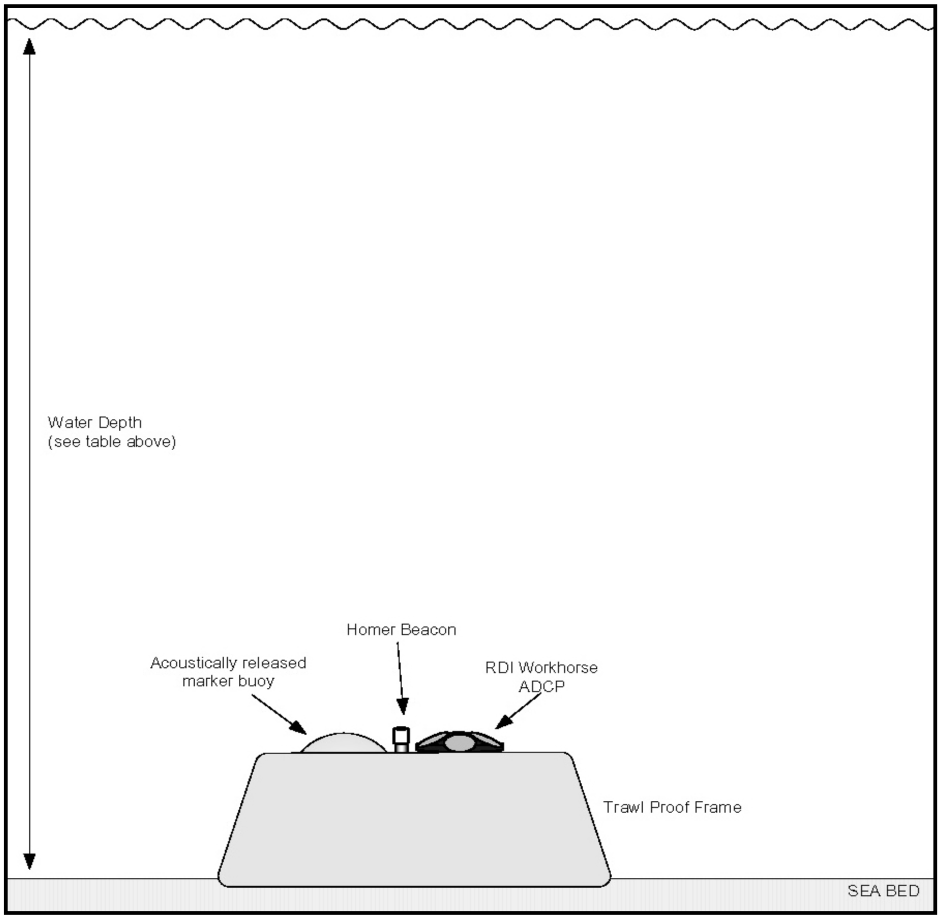
b- Current Measurements:

Current speed and direction were measured by Workhorse Acoustic Doppler Current Profiler (WH ADCP). The location comprised a self-contained RDI Workhorse Acoustic Doppler Current Profiler (WH ADCP) in upward-looking mode to measure current speed and direction throughout the water column. The instrument at this location was deployed in trawl-proof frames approximately 0.4 m. above the seabed. A typical configuration is shown in Fig. 4.

The instruments were fixed at two stations:

1. Deep Water Station: The instrument was installed at water depth 29 m at 31° 34.90` N and 032° 15.93` E, witha sampling rate of 10 minutes.

2. Shallow Water Station: The instrument was installed in the shallow water at water depth 8 m at 31° 22.98` N and 032° 07.00` E, with a sampling rate of 10 minutes.



level station

Fig. 4: Configuration of currentmeter.

METHODS OF ANALYSES

i. Basic Statistics:

Data were processed for the measured period, from the first of February-1999 to the end of January-2000. Maximum, mean, standard deviation, variance and valid number were calculated for wind, and current parameters.

ii. Time Series:

Time Series of hourly, daily and monthly wind and current speed and directions were presented and graphically plotted.

iii. Joint Frequency Analysis:

Joint frequency distributions have been presented for wind and current data. The directional analysis describes the number of events and percentage occurrences of speed in 22.5° sectors.

- Joint frequency distribution of wind speed against wind direction,
- Joint frequency distribution of current speed and current direction.

iv. Wind and Current Roses:

Wind and current roses for the full measurement during the period from February-1999 to January-2000 are presented for the investigated area. Percentage frequency of wind and current speeds are also presented for each direction.

v. Histograms, Scatter Plots and Correlations:

Histogram, scatter plot and correlation between wind and current speed and direction are presented as follows:

- Current speed and wind speed.
- Current direction and wind direction.

RESULTS AND DISCUSSION

1- Meteorological Characteristics

The basic statistical analysis (maximum, minimum, mean, standard deviation, range, variance, skewness, kurtosis and valid number) for different meteorological parameters during the period from February 1999 to January 2000 are shown in Table (2).

- Meteorological results indicated that the summer months were dry and atmospheric pressure was relatively constant. Atmospheric pressure during the winter months was more dynamic with depressions passing through the region, giving rise to variation in air temperature and increased wind speeds.
- The maximum and minimum atmospheric pressures measured at the Wakar Platform were 1029hPa (January 2000) and 1001hPa (July 1999) respectively. The maximum and minimum air temperatures were 28.3°C (July 1999) and 6.5°C (January 2000).
- The maximum 10-minute mean wind speed measured on the Wakar Platform was 20.5 m/sec on 18 January 2000 at 11:20 and 12:10; the wind direction was from the west-northwest and west respectively.

Fig (5) illustrates the time series of recorded wind speed and direction for different months and the monthly mean wind speed for the whole period. From this figure it is clear that the wind is strong and variable during winter, while it is weak and steady during summer. The strongest wind is generally coming from the NW direction during the winter storms. The maximum monthly mean wind speed was 6.9 m/sec (Jan. 2000).

Table (3) shows the joint frequency distribution of wind speed against wind direction while Fig. (6), provides an overview of the wind distribution for the investigated area, by depicting the distribution of the wind speed and wind frequency for the basic sixteen directions. From this figure one may conclude that:

- **During spring:** The winds were predominant from the sector NNW with percent 18.83 % and the secondary direction was from NW and N with percent 17.53 % and 17.17 % respectively.
- **During summer**: The primary wind direction was from NNW with percent 30.14 % and the secondary one was from NW with percent 28.25 %.
- **During autumn:** The primary wind direction was from E with percent 19.40 % and the secondary one was from N and ENE with percent 12.54 % and 11.62 % respectively.
- **During winter:** The wind direction is more variable during winter months. The prevailing wind direction was from ENE and NE with percent 11.46 % and 11.02 % respectively and the secondary wind direction was from N with a percent of 10.09 %.
- **The predominant wind direction during the whole period** was from the sector NNW with a percent of 14.14 % and the secondary one was from N and NW with percent 13.59 % and 12.86 % respectively.
-

Table 2: Basic statistical analyses for different meteorological parameters.

Descriptive Statistics	Air Temperature (°C)	Atmospheric Pressure hPa (mb)	Wind Speed (m/sec)
Mean	20.07	1014.5	4.98
Confid. -95.0%	20.03	1014.5	4.95
Confid. 95.0%	20.11	1014.6	5.00
Minimum	6.5	1000.9	0.00
Date of Min.	27-Jan-2000	14-Jul-1999	----
Maximum	28.3	1028.6	20.5
Date of Max.	19-Jul-1999	30-Jan-2000	18-Jan-2000
Range	21.8	27.7	20.5
Variance	15.4	26.23	6.64
Std.Dev.	3.92	5.12	2.58
Skewness	-0.0678	-0.1177	1.0973
Kurtosis	-1.0979	-0.5139	2.2767

Table 3: Joint frequency distribution of wind speed against wind direction during the period from 1 Feb. 1999 to 31 Jan. 2000.

Wind Speed (m/sec) / Wind Direction (True Wards)	0.5 <2.1	2.1 <3.6	3.6 <5.7	5.7 <8.8	8.8 <10.8	>10.8	All speeds
N	1.58	7.67	3.26	0.83	0.22	0.03	13.59
NNE	0.72	3.98	2.34	0.23	0.15	0.06	7.48
NE	0.96	3.91	2.21	0.57	0.05	0.02	7.72
ENE	1.11	3.26	2.89	1.18	0.06	0.01	8.51
E	0.68	2.75	2.86	1.94	0.28	0.01	8.51
ESE	0.55	1.40	1.27	0.59	0.13	0.00	3.95
SE	0.82	1.07	0.54	0.13	0.00	0.00	2.56
SSE	0.80	0.48	0.10	0.05	0.00	0.00	1.43
S	0.28	0.39	0.32	0.06	0.00	0.00	1.04
SSW	0.16	0.48	0.15	0.03	0.00	0.00	0.82
SW	0.16	0.48	0.23	0.02	0.00	0.00	0.88
WSW	0.27	0.55	0.49	0.42	0.18	0.13	2.04
W	0.64	1.54	0.97	1.31	0.75	0.45	5.66
WNW	1.08	2.95	2.07	1.29	0.43	0.55	8.36
NW	1.23	4.62	4.21	2.22	0.39	0.19	12.86
NNW	1.50	6.85	4.42	1.16	0.17	0.04	14.14
All directions	12.52	42.39	28.32	12.03	2.81	1.48	99.42% Calm 0.58%

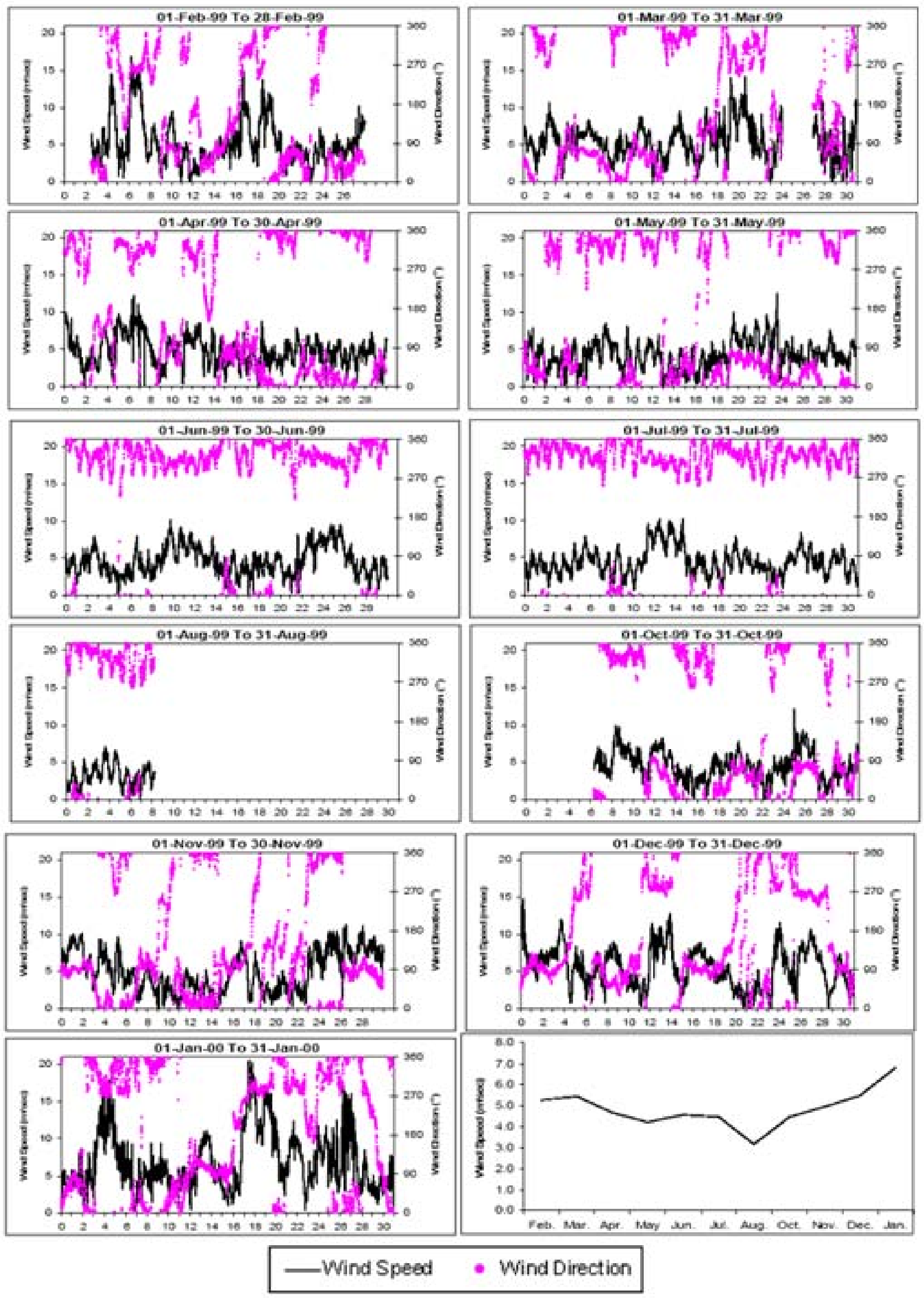


Fig. 5: Time series of the hourly wind speed and direction and monthly mean wind speed during the period from 1 Feb. 1999 to 31 Jan. 2000.

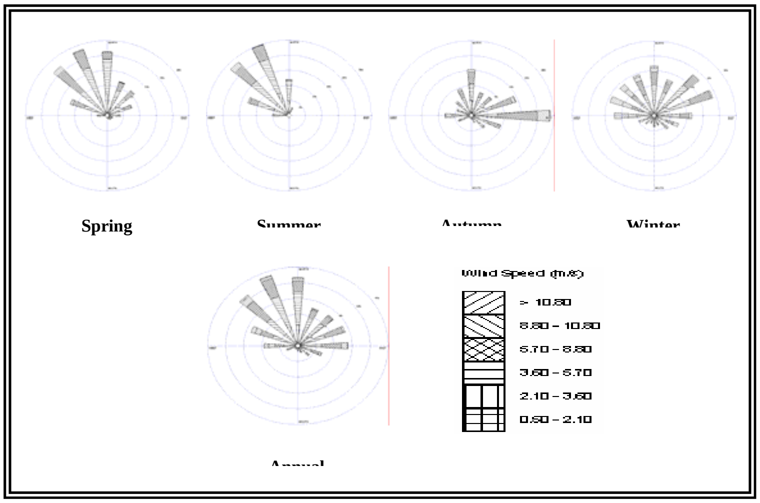


Fig. 6: Seasonal and annual percentage frequency of wind speed and direction during the period from 1 Feb. 1999 to 31 Jan. 2000.

2. Current Patterns

2.1.<u>Current at Shallow Water Station (8m):</u>

The basic statistical analyses (maximum, mean, standard deviation, variance and direction and date of max.) for current speed at shallow water at three levels (near surface, intermediate depth and near bottom) are summarized in Table (4). From this table it is clear that the mean current speed varies between 0.145 m/s at surface and 0.095 m/s near bottom.

The maximum recorded current speeds during the whole period were 0.87; 0.81 and 0.75 m/s for near surface (1m); intermediate (4m) and near bottom (6 m) respectively. The maximum speeds were found during Jan. 2000.

<u>Near Surface (1 m depth)</u>:

The seasonal and annual variations of current speed and direction near surface are shown in Fig. (7). From this figure it is clear that:

- **During spring:** The main current direction is SE and the secondary one is ESE with frequencies 47.6% and 18.4% respectively. The maximum current speed is 0.42 m/sec. More than 52.9 % of the current speeds during this season lie between 0.10 m/sec and 0.20 m/sec.
- **During summer:** Predominate current direction is SE and the secondary one is ESE with frequencies 36.8% and 30.6% respectively. The maximum current speed is 0.47 m/sec. Most of current speed during this season lies between 0.10 m/sec and 0.20 m/sec, with a percent 46.6 % of all speeds.
- **During autumn:** The prevail current direction is ESE with frequency 31.2 % and the secondary one is SE and WNW with frequencies 14.9 % and 14.5 % respectively. The maximum current speed was 0.55 m/sec while 40.3 % of all speeds less than 0.10 m/sec.
- **During winter:** The primary current direction is SE with frequency 28.3 %, while maximum current speed is 0.87 m/sec. The highest current speed exists during this season.
- **During the whole period (February-1999 – January-2000):** Table (5) shows the joint frequency distribution for current speed and direction near surface at depth 1m. The prevailing current direction during this year is

ESE and the secondary one is SE with frequencies 28.6 % and 28.3 % respectively.

Figs. (8 and 9) show the scatter plot and histograms of current speed against wind speed and current direction against wind direction respectively near surface at shallow water. From this figure we can conclude that there is a good correlation between wind and current speeds with a correlation coefficient of about 0.502 which indicate that the water current in this region affected by wind. The wind directions scattered between the NW and NE sectors while, the current direction is almost toward SE.

Table 4: Basic statistical analyses for current speed at shallow water station during the period from 1 Feb. 1999 to 31 Jan. 2000.

Descriptive Statistics	Current Speed at Shallow Water (m/sec)		
	Near Surface (1m)	Intermediate Depth (4m)	Near Bottom (6m)
Mean	0.145	0.114	.095
Confid. -95.000%	0.144	0.113	0.094
Confid. 95.000%	0.146	0.115	0.096
Maximum	0.87	0.81	0.75
Date of Max.	27-Jan-00	27-Jan-00	27-Jan-00
Direction of Max.	ESE	ESE	ESE
Variance	0.009	0.007	0.006
Std. Dev.	0.0974	0.08485	0.07479

Table 5: Joint frequency distribution of current speed and direction for shallow water station at 1 m depth during the period from 1 Feb. 1999 to 31 Jan. 2000.

Current Speed (m/sec) / **Current Direction (True Wards)**	**0.0 <0.1**	**0.1 <0.2**	**0.2 <0.3**	**0.3 <0.4**	**0.4 <0.5**	**>0.5**	**All Speeds**
N	0.58	0.22	0.02	0.00	0.00	0.00	0.82
NNE	0.77	0.15	0.00	0.00	0.00	0.00	0.92
NE	1.07	0.12	0.01	0.00	0.00	0.00	1.19
ENE	1.74	0.73	0.18	0.00	0.00	0.00	2.65
E	3.76	3.22	1.60	0.25	0.04	0.00	8.89
ESE	7.06	12.81	4.77	2.30	1.20	0.48	28.62
SE	6.74	13.31	6.29	1.36	0.44	0.11	28.25
SSE	2.92	2.21	0.35	0.05	0.00	0.00	5.53
S	1.53	0.48	0.03	0.00	0.00	0.00	2.03
SSW	0.87	0.07	0.00	0.00	0.00	0.00	0.95
SW	0.75	0.04	0.00	0.00	0.00	0.00	0.79
WSW	0.75	0.14	0.00	0.00	0.00	0.00	0.89
W	1.40	0.85	0.12	0.00	0.00	0.00	2.38
WNW	2.52	4.24	1.49	0.66	0.10	0.00	9.01
NW	1.87	1.68	1.08	0.47	0.04	0.00	5.13
NNW	0.91	0.80	0.17	0.07	0.00	0.00	1.95
All Directions	35.24	41.06	16.12	5.16	1.82	0.59	100

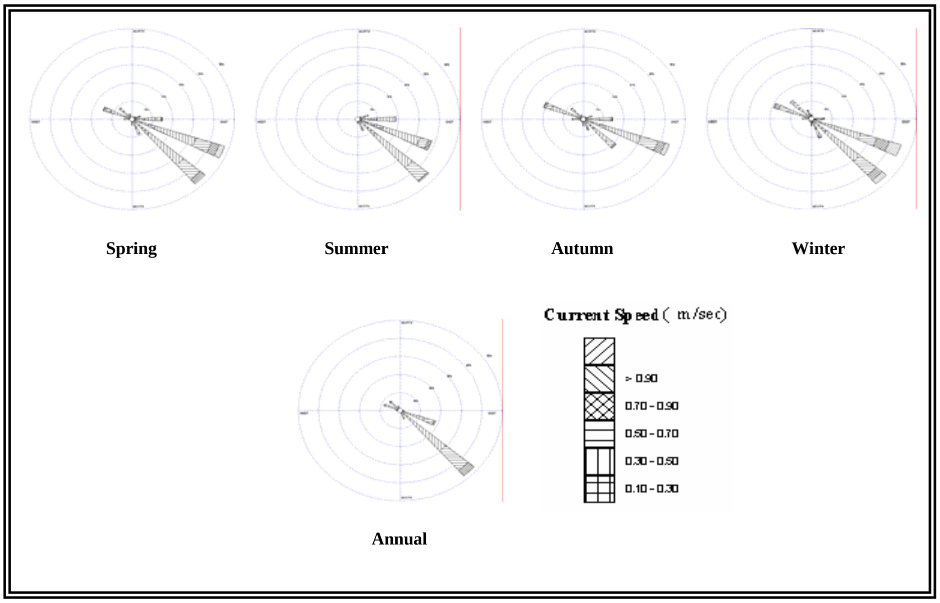


Fig. 7: Seasonal and annual percentage frequency of water current at 1 m depth at shallow water station during the period from 1 Feb. 1999 to 31 Jan. 2000.

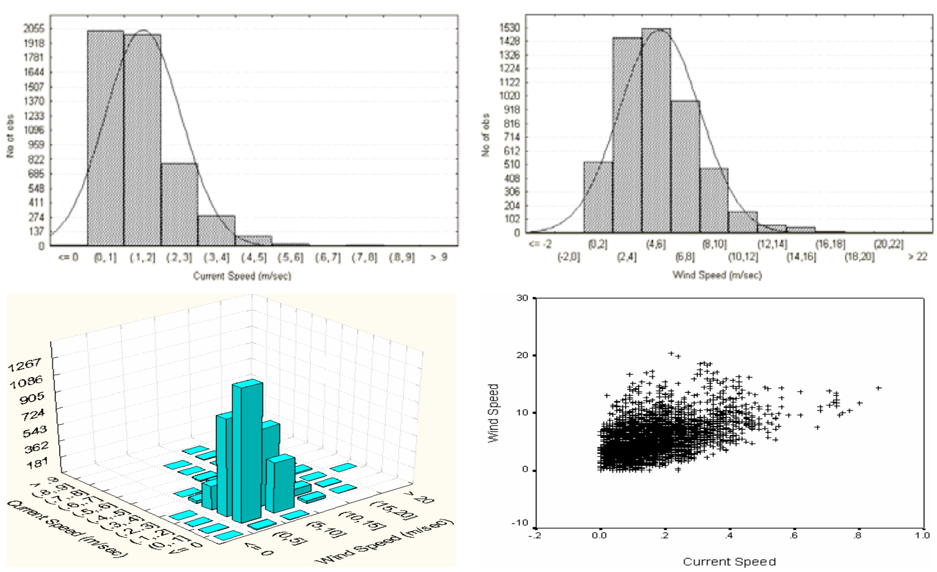


Fig. 8: Scatter plot and histograms of current speed against wind speed at shallow water station at 1 m depth during the period (Feb. 1999-Jan. 2000).

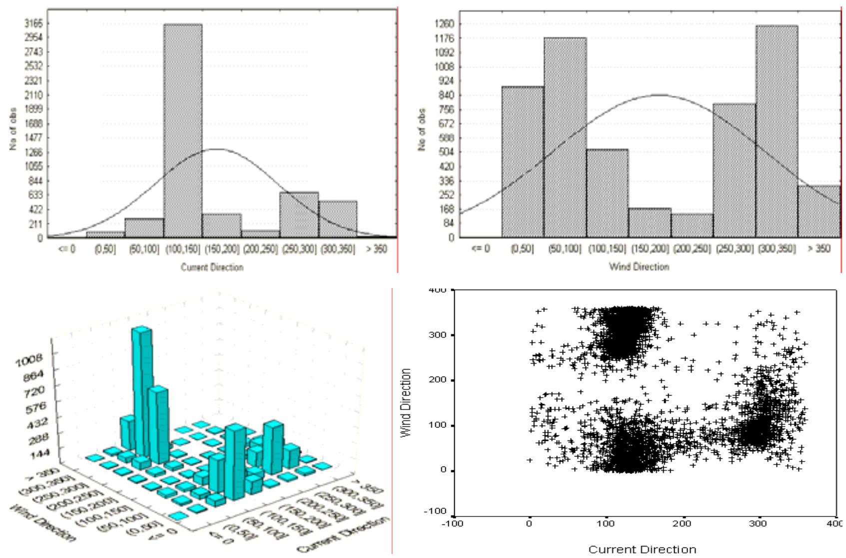


Fig. 9: Scatter plot and histograms of current direction against wind direction at shallow water station at 1 m depth during the period (Feb. 1999-Jan. 2000).

b. Intermediate Depth (4 m depth):

The seasonal and annual variations of current roses at the intermediate depth are shown in Fig. (10).

- **During spring:** The main current direction is SE and the secondary one is ESE with frequencies 39.3 % and 29.6 % respectively. The maximum current speed recorded during this season was 0.3 m/sec.
- **During summer:** The main primary direction is ESE and the secondary one is SE with frequencies 33.9 % and 33.4 % respectively. The maximum current speed is 0.39 m/sec in ESE direction.
- **During autumn:** The primary current direction is ESE with a percent 31.2 % of all directions and the secondary one is SE and WNW with frequencies 14.9 % and 13.5 % respectively. The maximum recorded current speed is 0.54 m/sec. More than 53.3 % of current speeds less than 0.1 m/sec.
- **During winter:** The primary current direction is SE with a frequency 32.1 %, while the secondary one is ESE with a frequency 25.1 %. The maximum recorded current speed is 0.81 m/sec, with speeds greater than 0.5 m/sec in ESE and SE directions. The highest current speeds exist during this season.
- **During the whole period (February-1999 – January-2000):** The prevailing current direction is ESE and the secondary one is SE with frequencies 30.2 % and 28 % respectively. The maximum recorded current speed is 0.81 m/sec. About 50% of current speeds less than 0.1 m/sec.

Autumn

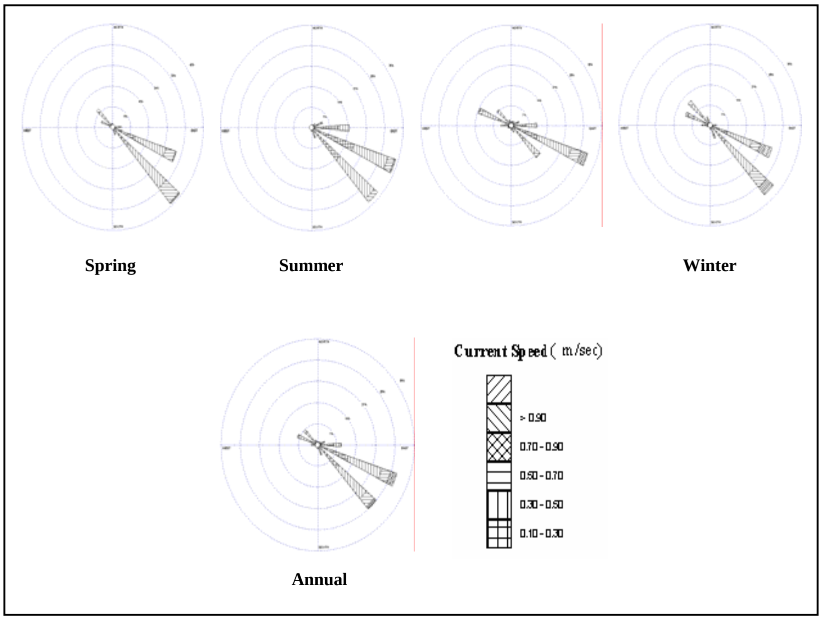


Fig. 10: Seasonal and annual percentage frequency of water current at shallow water station at 4 m depth during the period (Feb. 1999-Jan. 2000).

c. <u>Near Bottom (6 m depth):</u>

Fig. (11) shows the current roses for different seasons and the whole period at depth 6 m (near bottom).

- **During spring:** The main current direction is SE and the secondary one is ESE with frequencies 31.1 % and 23.6 % respectively. The maximum recorded current speed is 0.32 m/sec. The highest current speeds occurred in the ESE and SE directions respectively.
- **During summer:** The main primary direction is SE and the secondary one is ESE with frequencies 26.7 % and 25 % respectively. The maximum recorded current speed is 0.32 m/sec. About 70 % of the recorded current speeds less than 0.1 m/sec.
- **During autumn:** The primary current direction is ESE with a percent 24.6 % of all directions with maximum current speed of about 0.51 m/sec recorded in the same direction.
- **During winter:** The primary current direction is SE and the secondary one is ESE with frequencies 25.2 % and 19 % respectively. The highest current speeds are recorded in ESE direction with maximum current speed of 0.75 m/sec.
- **During the whole period (February-1999 – January-2000):** The prevailing current direction is ESE and the secondary one is SE with frequencies 23.1 % and 22.4 % respectively. The maximum recorded current speed is 0.75 m/sec.

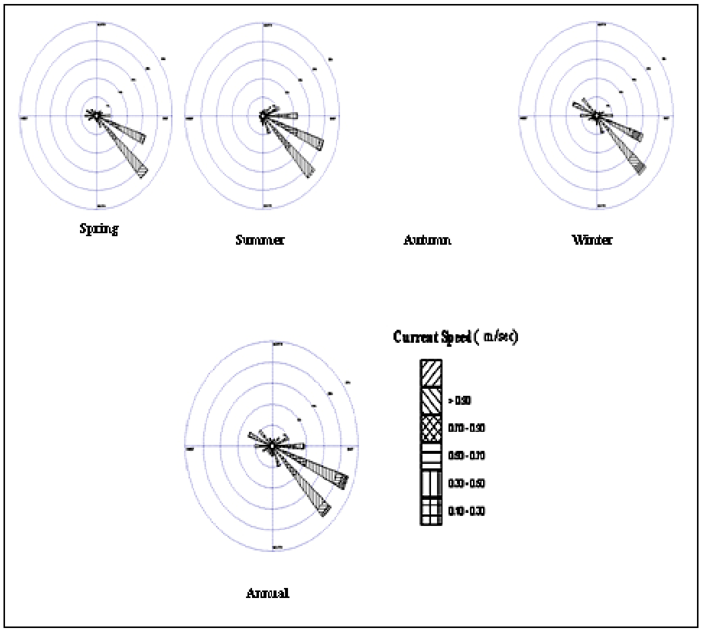


Fig. 11: Seasonal and annual percentage frequency of water current at shallow water station at 6 m depth during the period (Feb. 1999-Jan. 2000)

2.2. **Current at Deep Water Station (29m):**

The basic statistical analyses (maximum, mean, standard deviation, variance and direction and date of max.) for current speed at deep water at three levels (near surface, intermediate depth and near bottom) are summarized in Table (6).

From this table it is clear that the maximum recorded current speeds during the whole period were 0.50; 0.49 and 0.44 m/s for near surface (5m); intermediate (13m) and near bottom (23

m) respectively. All of the maximum speeds occurred during Jan. 2000 in the ESE direction. The mean current speed varies between 0.093 m/s near surface and 0.071 m/s near bottom.

a- Near Surface (5 m depth):

The seasonal variations of current speed and direction near surface at water depth 5 m are shown in Fig. 12:

- **During spring:** The main current direction is SE and the secondary one is ESE with frequencies 23.9 % and 15.1 % respectively. The maximum current speed is about 0.30 m/sec. Most of high current speeds occurred in the ESE and SE directions.
- **During summer:** The prevailing current direction is SE and the secondary one is SSE with frequencies 16 % and 15.1 % respectively. The highest values of current speed occurred in SE and SSE directions.
- **During autumn:** The primary current direction was SE with a percent 15.5 % and the secondary one was SSE with a percent 12.1 % of all directions. The maximum current speed was 0.34 m/sec with higher speeds between 0.3 m/sec and 0.4 m/sec in WSW and WNW directions.
- **During winter:** The primary current direction is SE and the secondary one is ESE

with frequencies 23.1 % and 11.8 % respectively. The maximum current speed is about 0.50 m/sec, with higher speeds greater than 0.5 m/sec in ESE direction. The highest current speeds during the period of investigation occurred during this season.

Table 6: Basic statistical analyses for current speed at deep water station during the period (Feb. 1999-Jan. 2000)

Descriptive Statistics	Current Speed at Deep Water (m/sec)		
	Near Surface (5m)	Intermediate Depth (13m)	Near Bottom (23m)
Mean	0.093	0.075	0.071
Confid. - 5.000%	0.0925	0.0745	0.070
Confid. 95.000%	0.0935	0.0755	0.072
Maximum	0.500	0.490	0.440
Date of Max.	19-Jan-2000	20-Jan-2000	21-Jan-2000
Direction of Max.	ESE	ESE	ESE, SE
Variance	0.004	0.003	0.003
Std. Dev.	0.06343	0.05831	0.05117

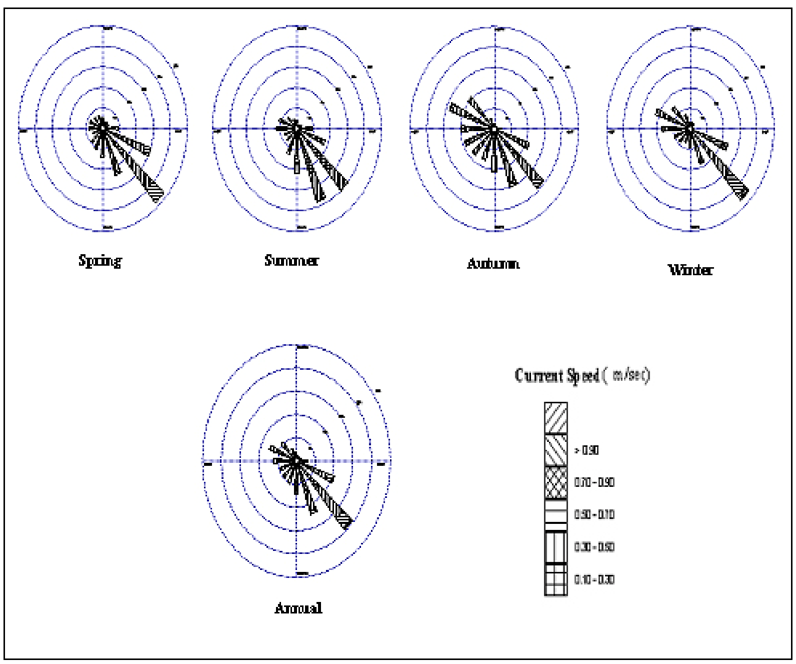


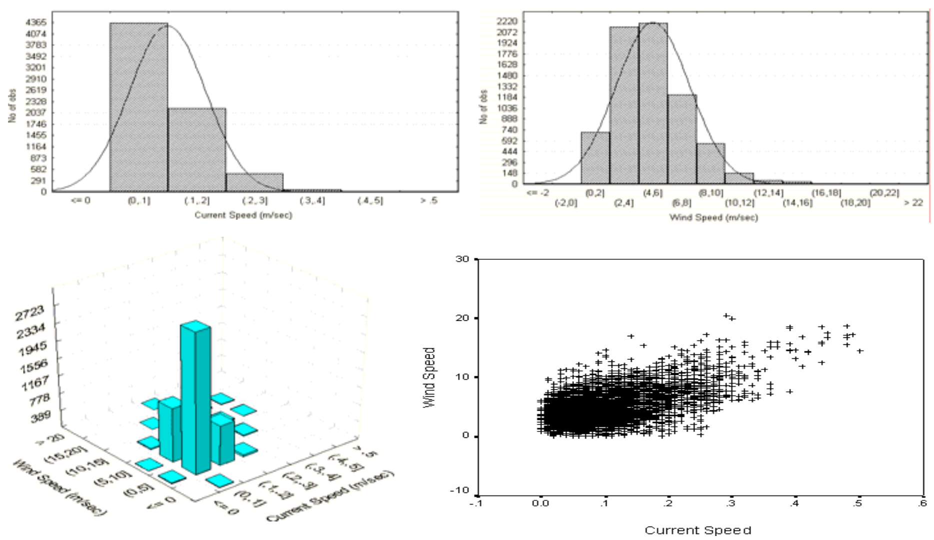
Fig. 12: Seasonal and annual percentage frequency of water current at deep water station at 5 m depth during the period (Feb. 1999-Jan. 2000)

- **During the whole period (February-1999 – January-2000):** Table (7) shows the joint frequency distribution of current speed and direction near surface at deep current station. The prevailing current direction is SE with frequency 19.6 % and the secondary one was SSE and ESE with frequencies 12.1 % and 10.7 % respectively. The maximum current speed is 0.5 m/sec.

Figs. (13 and 14) show the scatter plot and histograms of current speed against wind speed and current direction against wind direction respectively near surface at deep water station. From these figures it is clear that there is a good correlation between wind and current speeds with a correlation coefficient of about 0.541. The current directions scattered in a wide range than that for shallow water station.

Table 7: Joint frequency distribution of current speed and direction for deep water station at 5 m depth during the period (Feb. 1999-Jan. 2000)

Current Speed (m/sec) / Current Direction (True Wards)	0.0 <0.1	0.1 <0.2	0.2 <0.3	0.3 <0.4	0.4 <0.5	>0.5	All Speeds
N	0.15	1.64	0.12	0.00	0.00	0.00	1.92
NNE	0.15	1.18	0.05	0.00	0.00	0.00	1.38
NE	0.13	1.27	0.05	0.00	0.00	0.00	1.45
ENE	0.21	1.32	0.03	0.00	0.00	0.00	1.56
E	0.17	2.49	0.40	0.01	0.00	0.00	3.06
ESE	0.53	4.92	3.90	1.46	0.23	0.16	11.20
SE	0.79	7.86	8.43	2.85	0.38	0.06	20.37
SSE	0.85	6.81	4.62	0.70	0.02	0.00	13.00
S	0.57	4.89	2.29	0.07	0.00	0.00	7.82
SSW	0.32	3.90	1.35	0.02	0.00	0.00	5.58
SW	0.21	3.45	1.28	0.10	0.00	0.00	5.04
WSW	0.13	3.51	0.92	0.23	0.07	0.00	4.86
W	0.17	4.81	1.25	0.22	0.00	0.00	6.46
WNW	0.10	5.15	2.28	0.16	0.07	0.00	7.74
NW	0.15	3.60	1.80	0.11	0.00	0.00	5.65
NNW	0.12	2.41	0.38	0.00	0.00	0.00	2.92
All Directions	35.24	41.06	16.12	5.16	1.82	0.59	100



Correlation (0.541989**)**

Fig. 13: Scatter plot and histograms of current speed against wind speed at deep water station at 5 m depth during the period (Feb. 1999-Jan. 2000)

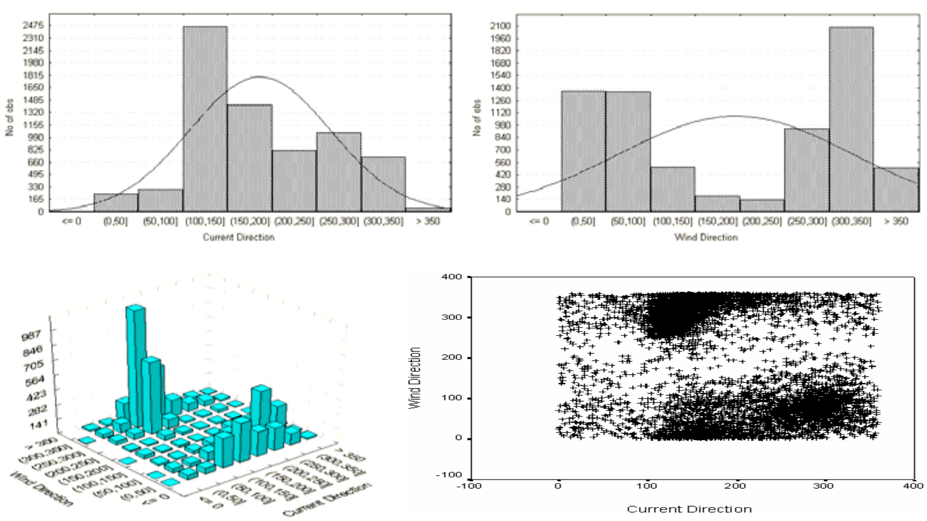


Fig.14: Scatter plot and histograms of current direction against wind direction at deep water station at 5 m depth during the period (Feb. 1999-Jan. 2000)

b. Intermediate Depth (13 m depth):

The seasonal variations of current speed and direction at the intermediate depth are presented in Fig. (15).

- **During spring:** The main current direction is SE and the secondary one is ESE with frequencies 25.7 % and 21 % respectively. The maximum current speed occurred during this season is 0.24 m/sec.
- **During summer:** The prevailing current direction is SE with frequency 21.6 % and the secondary one is ESE and SSE with frequencies 14.9 % and 14.2 % respectively. The maximum current speed is about 0.25 m/sec with higher values in SE, SSE and S directions.
- **During autumn:** The primary current direction is SE with frequency 16.5 % and the secondary one is SSE and ESE with frequencies 10.9 % and 10.4 % respectively. The maximum current speed is about 0.30 m/sec, with highest current speeds in SE direction.
- **During winter:** The main current direction is SE and the secondary one is ESE with frequencies 24.7 % and 11.9 % respectively. The maximum current speed during this season is about 0.50 m/sec.
- **During the whole period (February-1999 – January-2000):** The prevailing current direction is SE and the secondary one is ESE with frequencies 22.1 % and 14.5 % respectively. The maximum current speed is about 0.5 m/sec occurred during winter.

c. Near Bottom (23 m depth):

Fig. (16) shows the current roses of water current during different seasons and for the whole period near bottom at deep water Station

- **During spring:** The primary current direction is ESE and the secondary one is SE with frequencies 20.9 % and 16.5 % respectively. The maximum current speed is about 0.22 m/sec.
- **During summer:** The main current direction is SE and the secondary one is ESE with frequencies 18.2 % and 15 % respectively. About 87 % of the recorded current speeds during this season less than 0.1 m/sec.
- **During autumn:** The prevailing current direction is ESE and the secondary one is SE with frequencies 17 % and 16.6 % respectively. The maximum current speed is about 0.28 m/sec.
- **During winter:** The primary current direction is SE and the secondary one is ESE with frequencies 24.2 % and 15.9 % respectively. The maximum current speed recorded during this season is 0.44 m/sec in ESE and SE directions.
- **During the whole period (February-1999 – January-2000):** The prevailing current direction is SE and the secondary one is ESE with frequencies 18.8 % and 17.2 % respectively. The maximum current speed is 0.44 m/sec recorded during winter.

CONCLUSIONS

The present work is concerned with the analyses of available current and meteorological measurements at two stations in the coastal water in front of Lake Manzalah between Damietta and Port Said.

- **At Shallow Water Station (8 m depth):** Due to the shallow depth at this location the current flow was strongly rectilinear and was influenced by the wind field. Current flow was directed towards the ESE and WNW, with frequencies 52% and 13% respectively. Higher current speeds were towards the ESE with a maximum value of 0.87 m/sec recorded in January 2000. The mean current speed varies between 0.146 m/sec at 1 m depth and 0.095 m/sec at depth 6 m. Rapid changes in direction of the current flow were observed at this location, which appeared to be associated with abrupt changes in wind direction.

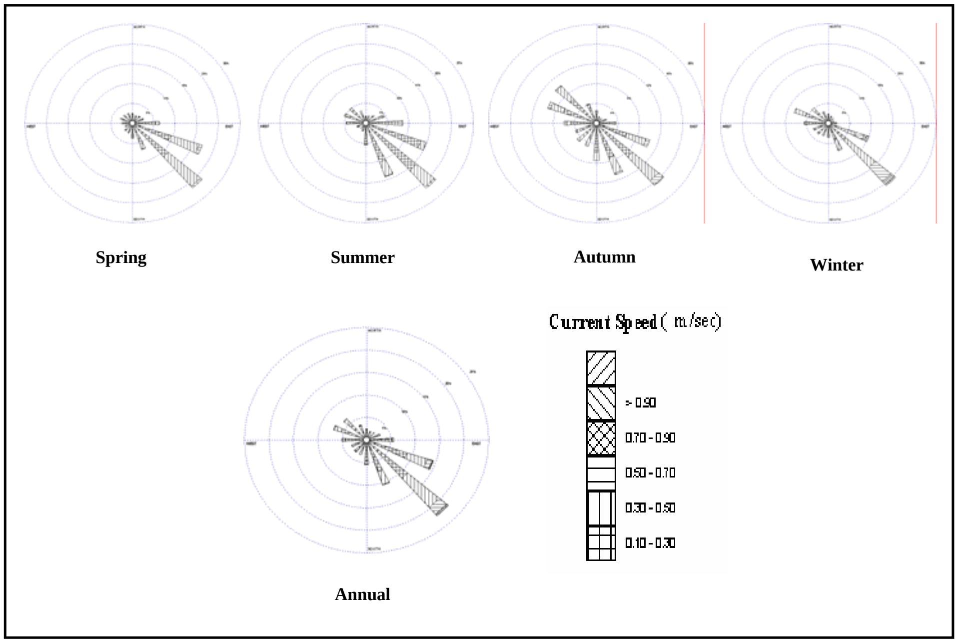


Fig. 15: Seasonal and annual percentage frequency of water current at deep water station at 13 m depth during the period (Feb. 1999-Jan. 2000).

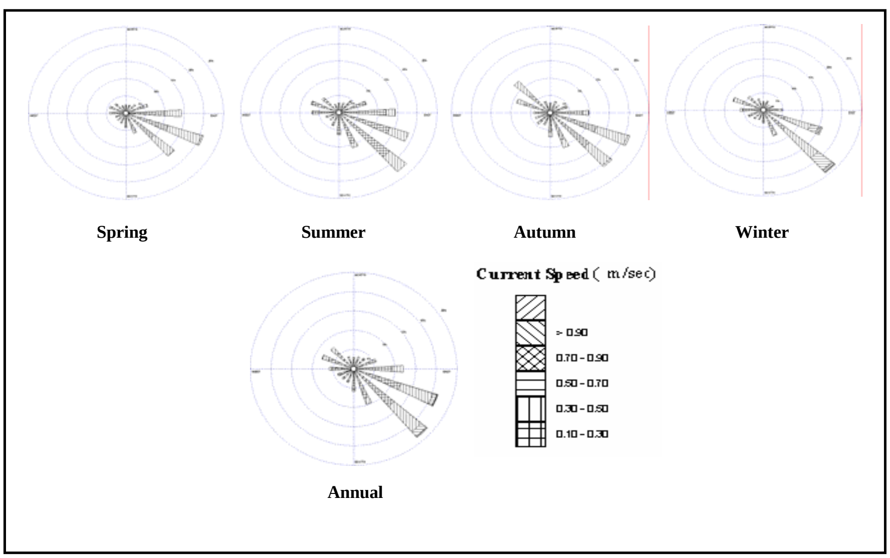


Fig. 16: Seasonal and annual percentage frequency of water current at Deep water station at 23 m depth during the period (Feb. 1999-Jan. 2000).

At Deep Water Station (29 m): The maximum current speed recorded was 0.50 m/sec towards ESE in 19 January 2000 and, was associated with the maximum wind event. The current speeds at this location where slightly lower than those recorded at shallow water (with a mean value varies between 0.071 m/sec and 0.093 m/sec). There was a tendency for the flow to be directed more towards the SE and NW with frequencies 29% and 14% respectively. During low current speeds, the directions were more variable and a diurnal variation in current speed and direction was often observed. Diurnal patterns in the current flow were often interspersed between periods of sustained flow towards the west or east when the wind conditions become more stable.

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