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TIDAL LEVELS IN ALEXANDRIA EGYPT

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ABSTRACT

The precise behaviours of tidal levels at Alexandria were investigated during one year period (1976). The main features of this semi-diurnal tide were defind by the tidal phenomena (MHWS, MHWN, MLWS, MLWN, HHWL AND LLWL) which determined from the major four harmonic constituents (M_2' S_2' K_1' and O_1) and compared witg the one obtained from the recorded tidal levels.

Theoretical and observed highest, lowest and mean astronomical tide were determind.

Tidal ranges were studied and showed largest value of 36 cm and smallest range of 4 cm.

Special attention has been paid to the theoretical relation of tide level (T.L.) to sea level (S.L.) which showed a lower of tide level by 0.02 cm, while the ratio of T.L to S.L is almost constant during a year.

Attention has been also paid to the frequency distribution of both T.L and S.L where the deviation between them have been noted during winter months which attributed to meteorological factors.

INTRODUCTION

The western harbour of Alexandria is limited by (31° 10'- 31° 12') N and (29° 50'- 29° 53') E. The hourly sea level heights were recorded with a tide gauge located in the inner part of this harbour, where the tide heights play a minor part as compared with other disturbance factors.

Since the practical significance of the tides is slight in Alexandria coastal water, they have not been investigated to a great extent, and will therefore be dealt with in this paper.

DATA AND METHODS OF ANALYSIS

The hourly values of the observed sea level for the year 1976 were used for determination of daily mean sea level by the x_o- filter method, monthly and annual levels were determind.

Daily mean high water (MHW), daily mean low water (MLW) were obtained from the average height of two consecutive high and two consecutive low water respectively. The mean tide level (T.L.) was determined as the average heights of MHW and MLW, while the theoretical T.L. considered as the mean of the heights (MHWS), (MHWN), (MLWS) and (MLWN).

Daily tidal range obtained from the difference between daily MHW and daily MLW. The maximum and minimum range are those of maximum and minimum recorded ranges during a month.

Mean high water spring (MHWS) and mean high water neap (MHWN) are the mean of high water during spring and neap tides respectively. Mean low water spring (MLWS) and mean low water neap (MLWN) are the mean of the low water during spring and neap tides respectively.

RESULTS

Harmonic Constituents of Tide :

Although Alexandria coastal waters are almost tideless but it may be interesting to examine to what extent the harmonic constituents which are representative of the tidal phenomenon.

The four principal harmonic constituents (M_2, S_2, K_1, and O_1) were obtained from the analysis of the hourly sea level heights (Doodson's method) for the period of 29 days by Moursy, 1976 which gave values very near to these obtained before from one year analysis (1916-1917) by Dr. Robert von sterneck. The amplitudes (H, in cm) and phases (g^o) of the major tidal constitnents are listed in table (1).

Tide prediction

The harmonic method has been used to predict hourly heights of sea level, were the height is expressed by the well known expression.

$$h = z + \sum_{i=1}^{N} f_i H_i \cos (O_i t + g_i)$$

where z is the mean sea level, in terms of a chosen zero level, N is the necessary number of harmonic constituents (M_2, S_2, K_1, and O_1), f_i, H_i, O_i and g_i are respectively, the node factor, amplitude, angular speed, and a further specified phase lage of the constituents, and t is the time.

Table 1.

Harmonic constituents for Alexandria.

constants	M_2		S_2		K_1		O_1	
	H. cm	g^o	H. cm	g^o	H. cm	g^o	H. cm	g^o
Moursy (1976)	7.19	325	4.34	309	1.64	317	1.34	300
Robert Von Sterneck (1916 - 1917)	7.19	305	4.06	319	1.67	303	1.26	271

A concept of the correspondence between the tidal curve based on the computed harmonic constants and the actual records for Alexandria is shown in fig. 1.

Tidal levels

Some of the more important terms connected with the tidal phenomena are determined to complete the description of tidal heights.

H.A.T. and L.A.T., the highest and lowest astronomical tide for each month of 1976 are given in table (2). These levels are not the extreme levels which can be changed by the contribution of meteorological and astronomical conditions.

Mean high water spring (MHWS) is obtained by averaging the heights of two successive high water during the period of spring tide of 24 h when the range of tide is greatest, then averaged throughout a year (Admiralty Tide table, 1986). The height of mean low water springs (MLWS) is the average height obtained by the two successive low waters during the same period, Table (3) shows the monthly and annual values of (MHWS) and (MLWS) for 1976.

The height of mean high water neaps (MHWN) is the average throughout a year of the heights of two successive high waters abtained during the period of neap tides, when the range of tides is least. The height of mean low water neap (MLWN) is the average height obtained from the two successive low waters during the same period, the monthly and annual values of (MHWN), (MLWN) are given in Table (3).

Mean tide level (MTL) was computed as the mean of the heights of (MHWS), (MHWN), (MLWS) and (MLWN), (46.7 cm), which is very near to the one obtained by which the heights of high and low water are used (46.3 cm), Table (4).

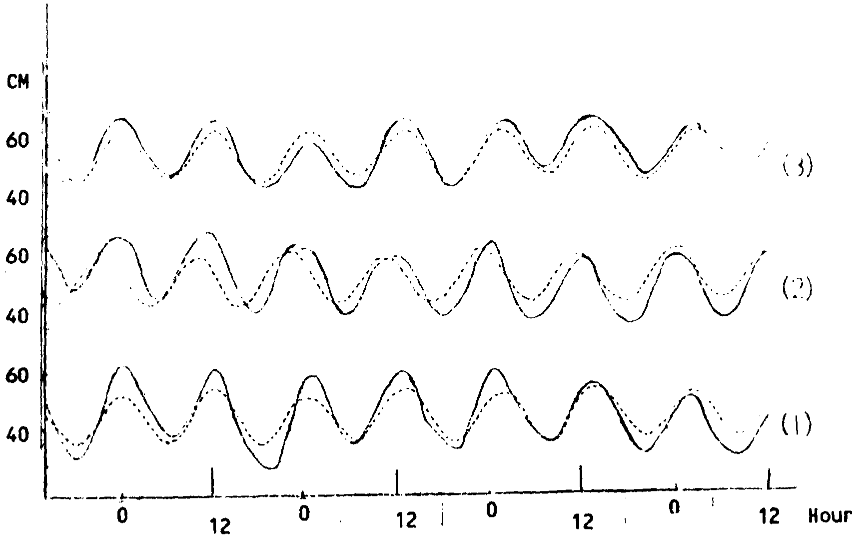

Fig. 1

Tidal variation at Alexandria during the selected periods of 1976.

1- Jan. 17-22
2- Sep. 7-10
3- Nov. 8-11

------- Theoretical sea level.
_______ Observed sea level.

Table 2.

Highest and Lowest astronomical tide for 1976.

month	J	F	M	A	M	J	J	A	S	O	N	D	Average
H.A.T cm	62	75	68	65	59	58	74	74	69	82	83	76	70.4
L.A.T cm	20	12	10	19	21	28	37	40	25	26	28	28	24.5

Table 3.

Recorded Seasonal values of Mean high water Spring (MHWS). Mean high water neap (MHWN), Mean low water spring (MLWS) and Mean low water neap (MLWN) in cm for 1976.

Month	MHWS	MHWN	MLWS	MLWN
JAN.	48.5	55.2	34.2	32.0
Feb.	42.7	55.5	22.2	33.7
Mar.	50.7	43.5	29.5	21.7
Apr.	59.7	45.0	32.2	27.5
May.	52.7	43.2	26.0	28.5
Jun.	57.2	48.7	33.7	34.0
Jul.	67.2	61.7	54.4	49.5
Aug.	70.5	66.5	44.0	50.0
Sep.	61.0	49.7	33.2	35.2
Oct.	68.7	61.7	40.7	46.5
Nov.	57.5	62.0	32.5	50.7
Dec.	63.2	62.0	42.2	51.5
Average	58.3	54.6	35.4	38.4

In an investigation of the basic properties of the tide in Alexandria, the theoretical relations concerning the tidal phenomena were obtained using the harmonic constituents as follows:

Spring constant:

Mean high water spring (MHWS) = MSL + $(M_2 + S_2)$ = 57.03 cm
Mean low water spring (MLWS) = MSL - $(M_2 + S_2)$ = 33.97 cm
Mean spring range = 2 $(M_2 + S_2)$ = 23.06 cm.

Neap constant:

Mean high water neap = (MHWN) = MSL + $(M_2 - S_2)$ = 48.35 cm

Mean low water neap = (MLWN) = MSL-$(M_2 - S_2)$ = 42.65 cm
Mean neap range = 2 $(M_2 - S_2)$ = 5.7 cm

Approximate highest high water level (HHWL) =
= MSL + $(M_2 + S_2 + K_1 + O_1)$ = 60.01 cm

Approximate lowest low water level (LLWL) =
= MSL - $(M_2 + S_2 + K_1 + O_1)$ = 30.99 cm

Highest range of tide = 2 $(M_2 + S_2 + K_1 + O_1)$ = 29.02 cm

Table 4.

Maximum, Minimum and Mean sea level ranges.
Means of high water (H.W), low water (L.W), tide level (T.L)
and sea level (S.L) in cm for the year 1976.

Month	Max. range	Min. range	Mean range	Mean H.W.	Mean L.W.	Mean T.L	Mean S.L	T.L/S.L
JAN.	27.5	5.5	17.6	47.6	29.8	38.7	39.0	0.99
Feb.	27.5	6.5	18.3	52.2	33.9	43.1	41.8	1.03
Mar.	34.0	3.5	19.5	45.1	26.7	35.9	36.9	0.97
Apr.	36.0	7.0	20.9	51.7	30.8	41.2	41.5	0.99
May.	31.5	9.0	19.7	47.9	27.9	37.9	37.9	1.00
Jun.	24.5	9.5	17.5	52.0	34.3	43.1	43.6	0.97
Jul.	31.0	7.0	18.3	63.5	45.1	54.3	54.7	0.99
Aug.	31.0	7.5	19.3	68.1	48.8	58.4	58.7	0.99
Sep.	31.0	4.0	18.6	56.6	38.0	47.3	46.3	1.02
Oct.	31.0	6.0	19.2	61.5	42.3	51.9	53.4	0.97
Nov.	28.0	9.0	18.8	62.5	43.6	53.1	52.0	1.02
Dec.	24.5	8.0	16.7	59.2	42.5	50.8	50.8	1.00
Mean	29.8	6.9	18.7	55.6	37.0	46.3	46.4	0.99

Where MSL is the mean sea level for Alexandria (45.5 cm), Moursy, 1989.

Comparing these results with the one obtained from the observed tide data, table (3), it seems that, in case of spring tide, they are nearly the same with a difference of approximately 1 cm, but a great difference during the neap tide, reached to 6 cm .

With respect to the recorded values of HAT and LAT, table (2) shows a higher value of 10.4 cm in high water and a lower value 6.5 cm in low water than the theoretical one, where the recorded tide is largely associated with variable atmospheric pressure and wind.

The highest high water springs may be expected about Aug. (70.5 cm) and the lowest low water springs are to be expected about Feb. (22.2 cm).

Attention must also be paid to the seasonal change in sea level, where it is usually small, but may be considerable, it reached 12 cm higher and 9 cm lower from the mean, table (4).

Tidal range and elevations

In order to get further information about the semidiurnal tides at Alexandria, the difference between the mean of the two highest water and the mean of the two lowest water per day were determined as the daily tidal range.

Analysing these ranges for the year 1976, it was found that, the largest mean range recorded during spring tide reached 36 cm, the average range was calculated as 18.7 cm and the smallest range found was 4 cm.

The recorded annual mean of maximum tide range, 29.8 cm (table (4)) agrees to some extent with the greatest possible range of tidal level (29.0 cm) based on the theoretical constituents.

Theoretical relation of tide level to sea level

On basis of the tidal phenomena, the mean sea level (MSL) is the average level calculated from a long series of equally spaced observations, while the mean tide level (MTL) is the mean of mean high and low water taken over a long period and may includes shallow water effects.

In the theory of tides, the relation between tide level and sea level may be expressed by the formula

$$MTL = MSL + M_4 \cos (2 M_2 - M_4) - (0.04 (K_1 + O_1)^2/M_2) \cos (M_2 - K_1 - O_1)$$

Where all terms have their usual significance in harmonic notation of the tide (Marmer, 1933).

Applying this formula for Alexandria coastal water, neglecting the quarter diurnal effects M_4, the mean tide level will be 45.48 cm which is lower than the mean sea level by 0.02 cm.

Table (4) shows the coincidence between monthly MTL and monthly MSL for 1976, also shows that the sea level is always higher than the tide level except in February and September. It is found that the variations on monthly values are smaller than in case of daily levels.

Frequency distribution of tide level and sea level

In order to give a picture of the distribution of both T.L and S.L during one year period (1976), the percentages frequency distributions are drawn for each month fig. 2. The deviation of S.L from T.L shows a marked difference between the winter and summer months where the contribution to sea level variations brought about by other factors (Meteorological and shallow water effect).

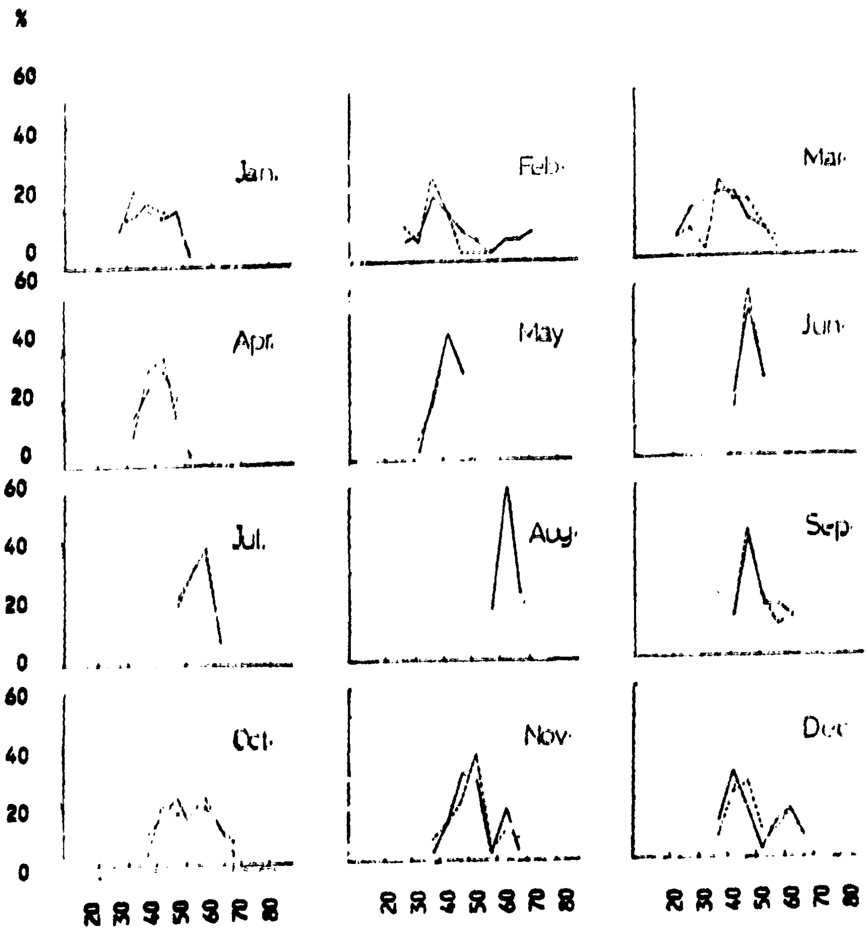

Fig. 2

Frequency distribution of Tide level (T.L) and sea level (S.L)

for 1976. ________ (T.L) ------- (S.L)

SUMMARY AND CONCLUSIONS

The tide of Alexandria coastal water is of semi-diurnal character, it is generally weak, therefore, the fluctuations in sea level caused by the meteorological factors are marked.

The coincidence between the observed sea level and the computed curves baised on the harmonic constituents must be considered satisfactory.

In an investigation of the basic properties of tide, the theoretical relations concerning the tidal phenomena, (MHWS, MHWN, MLWS and MLWN) show a correspondance between these values and the one obtained from the observed tidal levels during 1976 except at neap tides.

The recorded values of HAT and LAT show a higher value of 10.4 cm in high water and a lower value of 6.5 cm in low water than in theoretical one which may be attributed to the variable atmospheric pressure and wind.

The highest high water spring may be expected about Aug. (70.5 cm) and the lowest low water spring are to be expected about Feb. (22.2 cm).

The most pronounced tidal range occurred at spring tides of April (36 cm) while the least pronounced range occurred at neap tides of September (4 cm). The greatest possible range of tidal level based on four constituents was 29.02 cm which agrees to some extent with the recorded maximum range (29.8 cm).

The theoretical relation of tide level (T.L) to sea level (S.L) showed a lower of tide level by 0.02 cm.

Frequency distributions of T.L and S.L showed a marked deviation during winter months.

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