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Characteristics of the Tides at the Two Main Harbours of Egypt

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ABSTRACT. Alexandria and Port Said are considered as two of the major harbours of Egypt, they exhibit the same seasonal sea level trend and nearly the same meteorological conditions. Slight differences in the periodical variations of the tide levels are observed. The general pattern of the sea level at the two harbours is the high values in summer and low ones in spring season. The monthly levels are below their averages during the first half of the year and above during the second half. The principal features of the semi-diurnal tide indicated a ratio of 4.0 between spring and neap ranges. The most pronounced ranges at Alexandria are between 20-30 cm with mean of 22.3 cm and the maximum does not exceed 60 cm. At Port Said the most marked ranges are between 30-40 cm and the mean is 36.8 cm while the maximum may reach more than 70 cm.

Introduction

For technical purposes, especially in shallow sea regions like Alexandria which is limited by (31° : 10`) N & (29° : 53`) E and Port Said (31° : 16`) N & (32° : 19`) E, the knowledge of the periodical variations and the duration of the different sea level ranges may be of considerable importance for navigational purposes and for coastal engineering projects. The deviations in the general phenomena of the sea level ranges and elevations have to be taken into consideration and may not be neglected. These deviations are based on the comparison between the theoretical and the recorded data. In this connection, the present study will deal with both observed and expected tidal ranges and elevations at the two main harbours of Egypt, Alexandria and Port Said.

Data and Method of Analysis

The main features of the semi-diurnal tide are defined by the height of high and low water during spring and neap tides, where the spring tides are the semi-diurnal tides

within a semi-lunar period of approximately 15 days which have the most pronounced range. They occur near the days of full moon and new moon, when the attraction of Moon and Sun reinforces each other. The neap tides are the corresponding tides with the least pronounced range. They occur near the times of the first and third quarters of the month, when Moon and Sun counteract each other.

The observed high water spring (HWS) and low water spring (LWS) for a month are the highest and the lowest sea level during spring tide. The observed high water neap (HWN) and low water neap (LWN) are the corresponding high and low water during the neap tide. The annual mean values were determined by the average over the 12 months of the year 1986.

The hourly heights of the sea level at Alexandria were taken from the records of the tide gauge installed in the innermost basin of the Western harbour since, 1949, (Sharaf El Din and Rifat, 1968). The instrument is an old machine of the floating type with one day recording sheets erected in a double well, an accuracy of 0.1 cm (Rady, 1979). The tide gauge at Port Said was constructed by the Suez Canal Company at the time the canal was inaugurated. It is the same type as Alexandria tide gauge and has the same accuracy.

The sea level records at Alexandria and Port Said harbours for one year period (1986) were analyzed to determine the principal terms related with the tidal phenomena (MHWS, MHWN, MLWS and MLWN), where the first two terms refer to the mean of high water during spring and neap tides while the second two are the mean of the low water during spring and neap tide respectively.

The hourly values of tidal records obtained over the one year (1986) at Alexandria and Port Said were subjected to the harmonic analysis described by Godin (1972) to appreciate the main four tidal constituents (M_2, S_2, K_1, O_1) at the two harbours. Table 1 shows these harmonic constants and their corresponding one which were obtained by Moursy (1976) for Alexandria and by Defant (1961) for Port Said. It is noted that there are slight differences in the harmonic components in the two parts of the table, which may be attributed to the different methods used, where the later were obtained by Doodson's method for the analysis of tidal observation for 29 days of continuous records.

TABLE 1. The amplitudes (H in cm) and the phases (g in degree) of the major tidal constituents at Alexandria and Port Said.

Station	M_2		S_2		K_1		O_1	
	H	g	H	g	H	g	H	g
Alexandria (1986)	7.9	330	4.5	310	1.8	300	1.4	290
Port Said (1986)	11.1	305	7.0	315	2.0	307	1.5	280
Alexandria (Moursy, 1976)	7.2	325	4.3	309	1.6	317	1.3	300
Port Said (Defant, 1961)	11.7	304	6.9	319	2.1	305	1.7	275

On the basis of the two principal semi-diurnal constituents M_2, S_2 and the two main diurnal constituents K_1, O_1 at Alexandria and Port Said for 1986 (Table 1), the following theoretical terms are obtained:

Mean high water spring (MHWS) = MSL + $(M_2 + S_2)$
Mean low water spring (MLWS) = MSL – $(M_2 + S_2)$

Mean high water neap (MHWN) = MSL + $(M_2 - S_2)$
Mean low water neap (MLWN) = MSL – $(M_2 - S_2)$

Highest high water level (HHWL) = MSL + $(M_2 + S_2 + K_1 + O_1)$
Lowest low water level (LLWL) = MSL – $(M_2 + S_2 + K_1 + O_1)$ (Doodson, 1957)

Where MSL is the mean sea level for the year 1986, which is 46.0 cm for Alexandria and 53.2 cm for Port Said. The other terms represent the amplitudes of the main four tidal harmonic constituents.

The monthly means of the high water level (HWL) and the low water level (LWL) are determined as the average of the highest and the lowest daily sea level respectively for the month. The highest daily sea level range was obtained as the difference between the highest and the lowest sea level for that day.

Results

In a discussion of sea level changes at the two harbours, Alexandria and Port Said, the seasonal sea level variations based on one year period are illustrated in Fig. 1, which shows that the mean sea level at Alexandria is 46.0 cm while it is 53.2 cm for Port Said. It is evident also that the sea level at Port Said is always higher than at Alexandria. However, the lowest sea level at the two harbours are observed during spring months (March, April and May). The highest sea level at Alexandria is recorded in summer months (July and August), while the more marked heights at Port Said occurred in summer and autumn months from July to November. This phenomenon was described by Striem and Rosenan (1972) for Eastern coast of the Mediterranean, where they concluded that during winter, the barometric pressure in the Central Mediterranean is lower than that in the Eastern basin and this would be compatible with a lower sea level in the Eastern Mediterranean. During summer, the barometric pressure in the Central Mediterranean is higher than that of the Eastern basin and this would be in line with the higher sea level values in that area. It is clear from the figure that the mean monthly levels are below their averages during the first half of the year and above during the second half.

The Principle Features of the Tidal Phenomenon

In an investigation of the basin properties of the tides at the two harbours, it may be sufficient to refer to the harmonic constituents for this area. The main four harmonic constants for Alexandria and Port Said for 1986 (Table I) show that the ratio between the ranges of the two main diurnal constituents K_1, O_1, and the two principal semi-diurnal constituents M_2, S_2 is close to 0.25 for Alexandria and 0.20 for Port Said. This means that the tide is semi-diurnal in character. Two tidal curves of the semi-diurnal

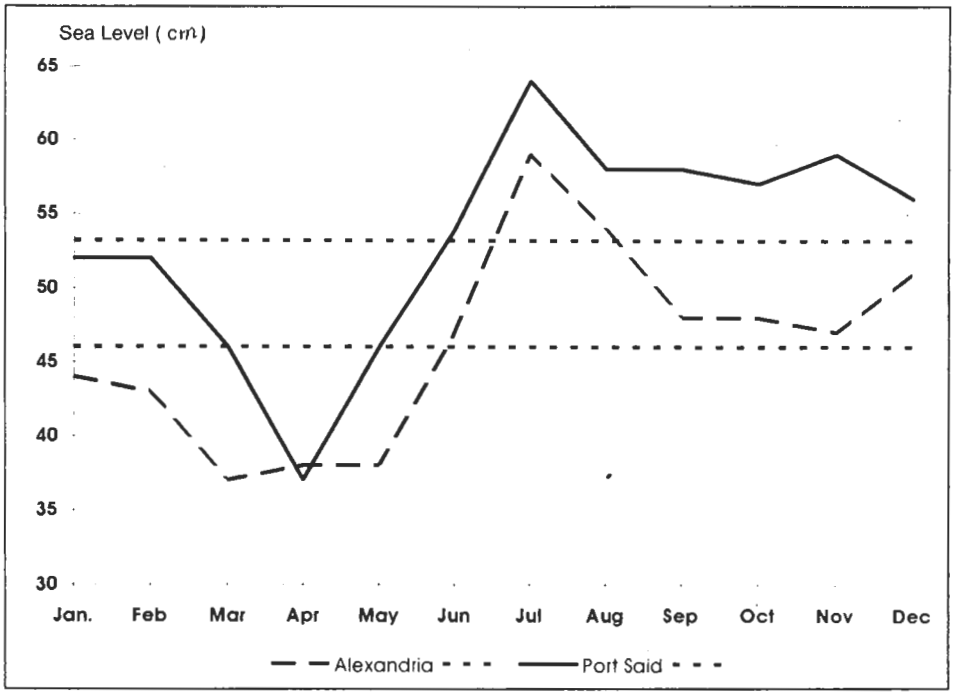

FIG. 1. Monthly mean sea level (cm) at Alexandria and Port Said harbours for 1986.

pattern during one month (July, 1986) for Alexandria and Port Said are shown in Fig. 2 as an example of the sea level variations in this area, they also show the difference between spring and neap tide.

The harmonic constituents calculated by different methods in Table 1 show that the ratio between the amplitudes of the two largest constituents S_2 and M_2 is approximately 0.6 for both Alexandria and Port Said, *i.e.* the amplitude of the S_2 constituents is slightly larger than half of the M_2. This fact illustrates that the tidal variations at the two harbours have the same pattern. Concerning the principal characteristic of the tidal levels, some of the more important terms connected with the tidal phenomena (MHWS, MLWS, MHWN, MLWN, HHWL and LLWL) should be pointed out. The theoretical values of these terms which have been determined by means of the four major tidal harmonic constituents given by Moursy (1976) and Defant (1961) are given in Table 2. Although the theoretical tidal terms show higher values at Port Said than at Alexandria, the ratio between the ranges of spring and neap tides at each station is roughly 4.0, which indicates that the tide at this part of the Mediterranean have the same pattern.

Considering the observed sea level data, the previous tidal terms were determined and reproduced in Table 2. It is obvious that the observed tidal terms differ from the theoretical, the deviations could be attributed to the effect of the meteorological factors (wind, atmospheric pressure). In general, the observed tidal terms at Port Said are always higher than that at Alexandria at high water and lower at the low water. The nat-

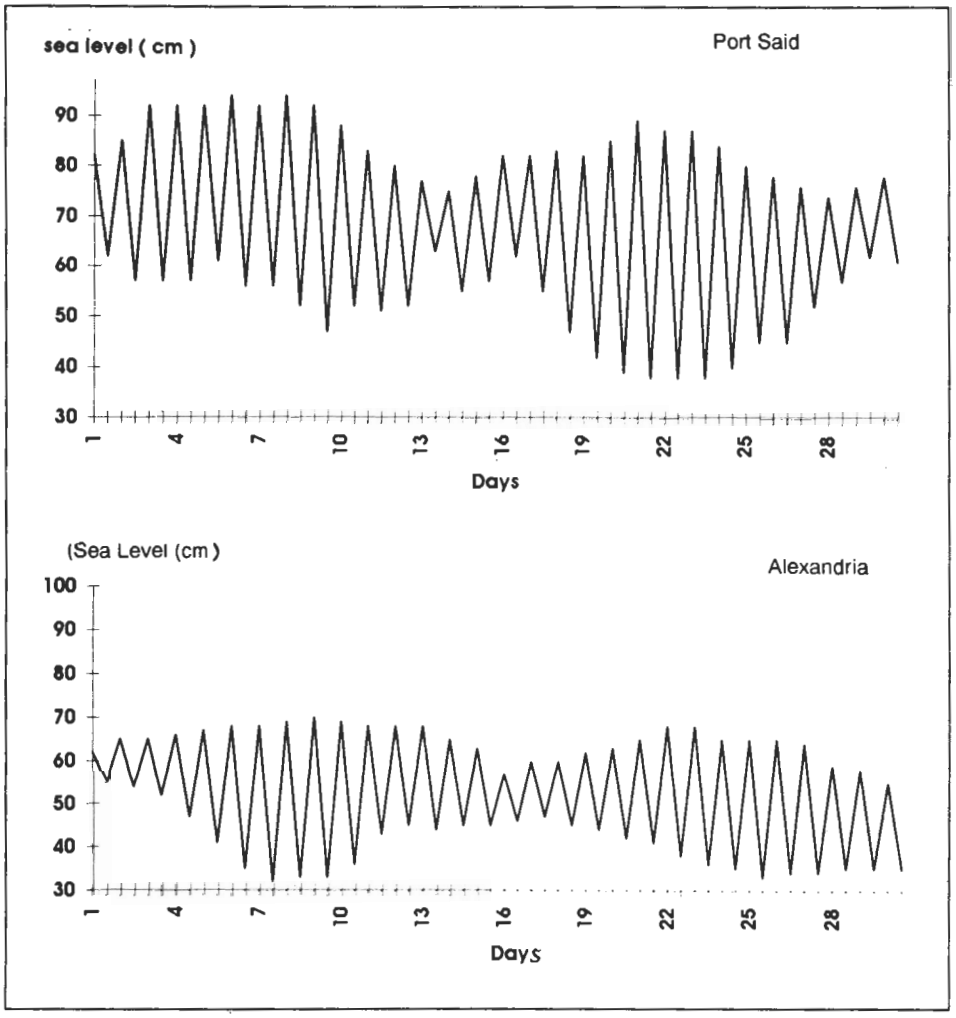

FIG. 2. Sea level variations during one month (July 1986) for Alexandria and Port Said.

TABLE 2. Theoretical and observed tidal terms at Alexandria and Port Said.

Tidal terms	Theoretical		Observed	
	Alexandria	Port Said	Alexandria	Port Said
Mean high water spring (MHWS)	57.5	71.8	62.4	81.6
Mean low water spring (MLWS)	34.5	34.6	34.4	31.5
Mean spring range (MSR)	23.0	37.2	28.0	50.1
Mean high water neap (MHWN)	48.9	58.0	51.0	67.6
Mean low water neap (MLWN)	43.1	48.4	43.0	42.3
Mean neap range (MNR)	5.8	9.6	8.0	25.3
Highest high water level (HHWL)	60.4	75.6	70.5	86.5
Lowest low water level (LLWL)	31.6	30.8	31.0	30.5
Highest range of tide	28.8	44.8	39.5	56.0

ural consequence is that the sea level of Port Said show more pronounced ranges than at Alexandria.

In an attempt to determine the response of the sea level variations to the meteorological factors, the astronomical tides were eliminated from the sea level data, using the method described by Rossiter (1959) which gives the residuals by subtracting the predicted tidal heights from the observed sea level data. These residuals are attributed to the changes in the atmospheric forces. The resultant astronomical tide $z(t)$ is expressed mathematically as follows:

$$z(t) = \sum_{i=1}^{n} f_i A_i \cos\left(V_i + U_i - g_i + \delta_i t\right)$$

where, A_i , g_i are the amplitude and phase of the main four tidal harmonic constituents, the other terms are defined by Godin and Taylor (1973).

On studying the relations between the variations in the sea level residuals and the corresponding changes in the local atmospheric pressure at the two stations, the correlation coefficient between the two variables have been obtained. With regard to Alexandria, the linear relation indicated a coefficient of –0.3850 while it is –0.4762 for Port Said. These values reveal a moderate inverse relationship between the sea level and the local atmospheric pressure.

From the previous examination of the prevailing wind at the investigated area, it was found that the lowering in the sea level were caused by the northerly wind while the rising resulted from the southerly wind (Hamed, 1983; Moursy, 1989). On studying the response of the sea level residuals to the changes in the prevailing wind, it is noticed that the linear relation between the two variables corresponds to a correlation coefficient of 0.3942 at Alexandria and of 0.5669 at Port Said. These relatively high correlation coefficients mean that the wind has an effective role in the generation of the sea level variations, but it is not the only factor.

The General Pattern of the Sea Level Range

On basis of the daily highest ranges of the sea level at the two harbours, Alexandria and Port Said, the monthly averages are determined and reproduced in Table 3. The data states that the annual mean value is 22.3 cm for Alexandria and 36.8 cm for Port Said. The lowest ranges are observed during summer months (from June to September), while the highest occurred in winter and spring summer months (from December to April). It is evident also that the ranges at Port Said are always higher than that at Alexandria, the average difference amounts to 15 cm.

TABLE 3. The monthly mean of the highest daily sea level ranges (cm) at Alexandria (Alex.) and Port Said (P.S.) for 1986.

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Alex.	23	24	23	24	23	21	21	21	21	22	22	23	22.3
P.S.	39	40	40	39	36	34	33	33	36	36	37	39	36.8

The same result is obtained from the frequency distribution of the sea level ranges at the two harbours. Table 4 shows that the most pronounced ranges at Alexandria lie between 20-30 cm and represent about 43.4% of the total frequency, while that at Port Said are between 30-40 cm and represents 32.1% of the total frequency. In this connection, it may also be mentioned that the sea level ranges at Alexandria do not exceed 60 cm while it may reach more than 70 cm at Port Said.

TABLE 4. The frequency (%) of the sea level ranges (cm) at Alexandria and Port Said (1986).

Range	0 > 10	10 > 20	20 > 30	30 > 40	40 > 50	50 > 60	60 > 70	70 > 80
Alex.	0.9	21.7	43.4	27.3	6.0	0.7	0	0
P.S.	0	3.0	20.0	32.1	30.3	12.5	1.6	0.5

Theoretical Relation of Tide Level to Sea Level

Further information about the semi-diurnal tide at the two stations are obtained from the relation between the tide level and the 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 include shallow water effects.

In the theory of tides, the relation between tide level and sea level are expressed by the formula:

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

where all terms have their usual significance in harmonic notation of the tide (Marmer, 1933). Applying this formula at the two harbours, neglecting the quarter diurnal effects M_4 and using 46.0 cm, 53.2 cm as the mean sea level for Alexandria and Port Said respectively, the mean tide level will be lower than the mean sea level by 0.018 cm at Alexandria and 0.005 cm at Port Said. These two values are insignificant with respect to the accuracy of the gauges (0.1 cm).

Conclusion

In spite of the higher values of sea level at Port Said than that of Alexandria, their seasonal variations exhibit the same trend, where high levels in summer and low ones in spring season. The principal feature of the tidal phenomenon was illustrated from the heights of water during spring and neap tides. It shows that the periodical variations of the tide at this part of the Mediterranean have the same pattern. The deviations in the recorded tidal terms from the expected ones are attributed to the external forces which are mainly of meteorological origin. The working up of the sea level ranges indicated that the annual mean value is 22.3 cm for Alexandria and 36.8 cm for Port Said. The most pronounced ranges at Alexandria are between 20-30 cm and the maximum range does not exceed 60 cm, while that at Port Said, the most marked ranges are between 30-40 cm and the maximum may reach more than 70 cm.

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خـــواص المـــد والجـــزر في أهـــم مينائـين بمصـــر

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المستخلص . بالرغم من أن مستوى سطح البحر في ميناء بور سعيد يكون أعلى من نظيرة في ميناء الأسكندرية إلا أن التغيرات الموسمية لسطح البحر في كلا المينائين تتبع نفس النظام حيث تكون أعلى ما يمكن خلال فصل الصيف وأقل ما يمكن خلال فصل الربيع . كذلك وجد أن الظواهر الأساسية للمد والجزر خلال فترات المد العالي والمد المنخفض في المينائين متوافقة . أما انحرافات هذه الظواهر عن معدلها الطبيعي فهو يرجع إلى تأثير بعض القوى الخارجية وخاصة العناصر الجوية مثل الرياح والضغط الجوي . بالنسبة لمدى المد والجزر لميناء الأسكندرية فهو يتراوح مابين ٢٠-٣٠ سم ولا يتعدى ٦٠ سم وأن متوسطه يصل إلى ٢٢,٣ سم بينما في بورسعيد فهو يتركز مابين ٣٠-٤٠ سم ومتوسطه يبلغ ٣٦,٨ سم ومن الممكن أن تصل إلى أكثر من ٧٠ سم .