

THE TIDAL RANGE AND THE OBSERVED SEA LEVEL VARIATIONS AT ALEXANDRIA HARBOUR

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مدى المد والجزر والتغيرات الناشئة في مستوى سطح البحر لمنطقة الإسكندرية

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من دراسة أقصى ارتفاع وانخفاض لمستوى سطح البحر بميناء الإسكندرية لمدة خمس سنوات (١٩٧٥ - ١٩٧٩) ، وجد أن مستوى سطح البحر في ارتفاع مستمر . أما تأثير عوامل الأرصاد الجوية على مستوى سطح البحر فقد ظهرت من دراسة التوزيع الترددي للمد اليومي لسطح البحر حيث أثبت أن المدى السائد يتراوح ما بين ٢٠ و ٢٥ سم بينما المتوسط الفعلي لمدى المد والجزر لمنطقة الإسكندرية ١٧,٥٦ سم . كذلك بمقارنة المدى المسجل فعلياً مع نظيره المتوقع في حالة أقصى وأقل مدى فقد وجد أن المدى المسجل يزيد عن المتوقع وهذه الزيادة ترجع إلى عوامل الأرصاد الجوية التي يزيد تأثيرها في فصل الشتاء .

Key Words: Sea level, Alexandria harbour.

ABSTRACT

On the basis of sea level observations of five years period (1975-1979), the basic properties of the tidal range at Alexandria are described. The problem of the combined effect of tides and meteorological factors on sea level is discussed. A more detailed description of this phenomenon is given by determining the frequency distributions of the tidal sea level range and also, by comparing the theoretical and the recorded range of tide during Spring and Neap tides. Finally, the mathematical relations between the greatest tidal range, the most pronounced sea level range and the average range are deduced.

INTRODUCTION

For sea coast protection at Alexandria, it is necessary to have accurate knowledge of the heights of highest and lowest water, as well as the extreme range of sea level and its seasonal fluctuations. For these purposes, the extreme heights of sea level variations and their mathematical properties are mentioned, which is important for coastal engineering.

Data and methods of analysis

For five years period (1975-1979), the daily mean high water and the daily mean low water were determined from the average heights of the two consecutive high and the two consecutive low waters respectively. The tidal range is the difference between the mean high and the mean low water.

The largest possible monthly sea level ranges were obtained from the difference between the highest high and the lowest low water for the month.

The theoretical greatest range of tide or the greatest range of sea level changes due to the tides was determined on the basis of harmonic tidal constituents by the relation.

$$\text{Highest range of tide} = 2 (M_2 + S_2 + K_1 + O_1) = 29.02 \text{ cm.}$$

$$\text{Where, } M_2 = 7.19 \text{ cm}$$

$$S_2 = 4.34 \text{ cm}$$

$$K_1 = 1.64 \text{ cm and } O_1 = 1.34 \text{ cm}$$

These four principal harmonic constituents were obtained from the analysis of the hourly sea level heights (Doodson's method) for the period of 29 days by Moursy, 1976 [1]. They gave values very near to the one obtained before by Dr. Robert Von Sterneck, and are published by The International Hydrographic Bureau [2]. These constituents are derived from observations for the period 1st July 1916 to 1st July 1917 as follows.

$$M_2 = 7.19 \text{ cm}$$

$$K_1 = 1.67 \text{ cm}$$

$$S_2 = 4.06 \text{ cm}$$

$$O_1 = 1.26 \text{ cm}$$

The theoretical mean Spring range = $2(M_2 + S_2) = 23.06$ cm.

$$\text{The theoretical mean Neap range} = 2(M_2 - S_2) = 5.70 \text{ cm.}$$

The recorded Spring tide range for a month was determined by the average of the two most pronounced ranges within a semi lunar period of approximately 15 days. The recorded Neap tide ranges are the corresponding tide range with the least pronounced range which occur near the times of the first and third quarters of the Moon.

Four terms are introduced in this study as follows

h_1 is the greatest theoretical tidal range.

h_w is the most pronounced total sea level range.

\bar{h}_t is the average range.

and h_m is the sea level range due to meteorological conditions.

RESULTS

Extreme heights of sea level at Alexandria

Because of the importance of the extreme heights of sea level in the construction of coastal installations, the monthly heights of mean high water and mean low water of the period (1975-1979) were determined and presented in table 1. In this table the seasonal changes in the extreme height levels give an average value of 37.47 cm. for mean low water above the zero of the tide gauge, while the corresponding average for mean high water is 55.03 cm. In addition, the lowest low waters are observed during spring months (March, April and May), while the highest are in summer months (July and August). However, the graph of the monthly mean sea levels (Fig. 1), exhibits a seasonal trend with low values in spring season and higher ones during summer. It can clearly be seen that the monthly mean values are below their average during the first half of the year while the rise is during the second half.

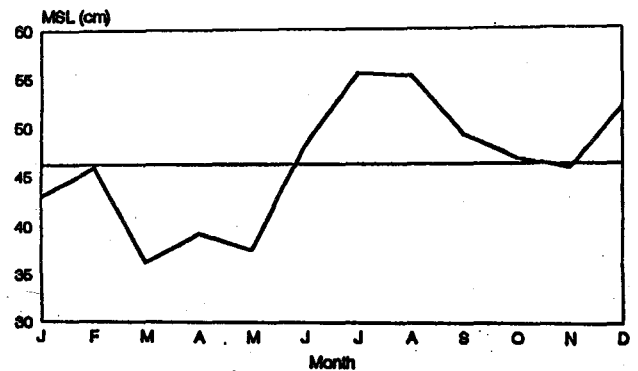


Fig. 1: The seasonal fluctuations of sea level at Alexandria.

The results of the annual mean for high and low water are shown in Fig. 2, which indicated a sea level rise. In this figure there is an upward trend for both the mean of low water and the mean of high water during the investigated period. On the other hand, the graph shows a downward trend for the tidal range which is the difference between the mean of high and the mean of low water. These results indicate that, although the sea level rises, the rate of increasing in low water is slightly more than the rate in the corresponding high water. This phenomenon may open the way for further research on the extreme heights for long periods.

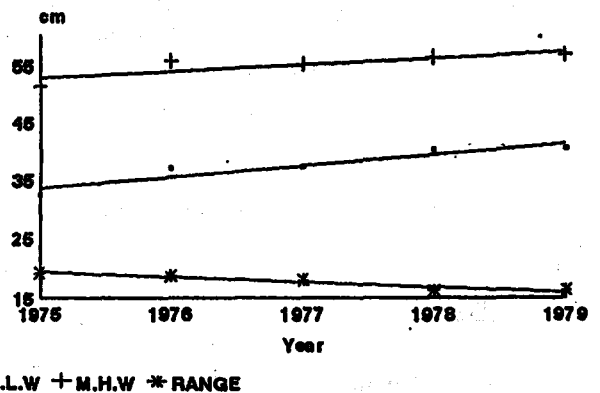


Fig. 2: The trend of mean high water, mean low water and mean range for (1975-1979).

It is apparent from the data shown in table 1 that the tide range at Alexandria have seasonal variations, although their deviations from the average value (17.56 cm.) may be considered insignificant. The minimum tide range are observed during summer months whereas the maximum tide range are recorded in spring months.

The combined effect of tides and meteorological factors on sea levels at Alexandria

On the basis of sea level observations of five years period (1975-1979), the difference between the observed highest high water and the lowest low water for a month was determined as the most pronounced total sea level range. This range represents the largest possible variations in sea level due to tide and meteorological factors.

Table 1
Mean high water (MHW), Mean low water (MLW), and the monthly tide range (cm) of the period (1975-1979)

Month	J	F	M	A	M	J	J	A	S	O	N	D	Mean
MHW	51.9	55.2	45.6	48.4	46.4	56.6	63.8	63.8	57.9	55.8	54.5	60.5	55.03
MLW	33.9	36.6	27.5	30.2	28.8	39.8	47.3	46.7	40.5	37.8	37.1	43.5	37.47
Tide range	18.0	18.6	18.1	18.2	17.6	16.8	16.5	17.1	17.4	18.0	17.4	17.0	17.56

The combined effect of tides and meteorological factors on sea levels at Alexandria

On the basis of sea level observations of five years period (1975-1979), the difference between the observed highest high water and the lowest low water for a month was determined as the most pronounced total sea level range. This range represents the largest possible variations in sea level due to tide and meteorological factors.

In order to give the characteristics of the regime of largest sea level variations due to meteorological events, the greatest range of sea level changes due to tides (29.02 cm) should be eliminated from the recorded largest monthly range of sea level variations (Table 2). The results are illustrated in Fig. 3, which shows a pronounced differences between winter and summer months. The lowest values are observed during the summer months (June to September) while the highest are during winter season from November to March which indicate that the contribution of meteorological factors on sea level ranges are more pronounced in winter.

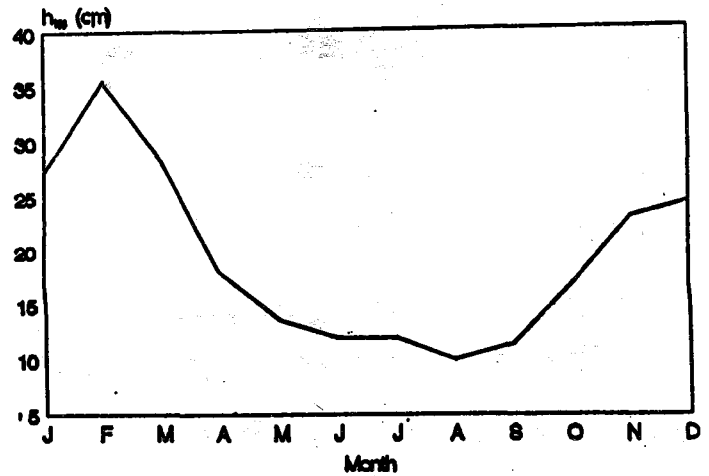


Fig. 3: Largest monthly range due to meteorological events.

Table 2
The largest monthly range of sea level variations (h_w) at Alexandria for the period (1975-1979).

Month	J	F	M	A	M	J	J	A	S	O	N	D	Mean
h _w (cm)	56.2	64.4	57.4	47.0	42.6	41.0	41.0	38.0	40.4	45.5	51.8	53.2	48.2

The frequency distribution of tidal range at Alexandria

Another example of the interaction of the meteorological contribution to sea level with the extreme values of the tides appeared from the frequency distributions of daily mean sea level range for the 5 years period. The results are given in table 3. Although the mean tide range was calculated as 17.56 cm., it can be seen from the frequency distribution that the range of tidal sea level variations are more pronounced in the values between 20-25 cm. and represents 28.1% of the total frequencies, which means that meteorological conditions are responsible for the more pronounced sea level range than the average value.

Table 3

The frequency distribution of daily sea level range at Alexandria

Range (cm)	5-10	10-15	15-20	20-25	25-30	30-35
Frequency %	14.5	19.1	23.7	28.1	12.8	1.8

The seasonal fluctuation in the range of Spring and Neap tide

Detailed knowledge concerning the tidal range and its relation to meteorological conditions is achieved by comparing the theoretical and the observed range of tide during spring and neap tide. In this connection, the monthly average for both spring and neap tide range were determined as well as the yearly average over the period of the 5 years, (Table 4).

The mean spring range determined on the basis of harmonic tidal constituents is 23.06 cm., while the corresponding recorded one is given in Table 4 and determined from the average spring tide range of five years is 26.19 cm. The same result was obtained for the neap tide range, where the theoretical one is 5.70 cm while the observed is 7.73 cm. It is noticed that both the recorded spring and neap tide range are higher than the calculated one which prove the fact that the sea level is consequently affected by the variations in the meteorological elements.

Table 4
Recorded monthly mean of spring and neap tide range (cm) of the period (1975-1979)

Month	J	F	M	A	M	J	J	A	S	O	N	D	Mean
Spring range	26.4	27.7	27.2	27.2	25.7	24.4	24.6	25.6	26.1	27.6	25.9	25.9	26.19
Neap range	7.8	8.2	6.3	9.4	9.2	9.2	8.0	6.5	5.7	7.0	7.7	7.8	7.73

The mathematical properties of the tidal range

From the previous discussion on the relation between the greatest theoretical tidal range (h_t) and the most pronounced total sea level range (h_w), we obtain the ratio

$$h_t / h_w = 0.60 \quad (1)$$

Taking into account $h_w = h_t + h_m$, where h_m corresponding to the largest possible range due to meteorological conditions, we may write

$$h_m / h_w = 0.40 \quad (2) \text{ and } h_m = 2/3 h_t \quad (3)$$

The last equation shows that the possible largest range of sea level variations due to meteorological conditions is nearly 2/3 of the largest range of tides.

If we consider $\bar{h}_t = 17.56$ cm is the average range of tide for the investigating period, then

$$\bar{h}_t / h_t = 0.60 \quad (4)$$

From equation (1) and (4) we obtain

$$h_t / h_w = \bar{h}_t / h_t \quad (5)$$

In this connection it must be pointed out that the above results are based on a rather restricted amount of sea level data. (Daily sea level of 5 years).

CONCLUSION

The heights of highest and lowest sea level in Alexandria indicating a sea level rise. The recorded tide range of Alexandria harbour shows a seasonal fluctuation, it also gives a more pronounced range than the computed one. These departures may be attributed to the effect of meteorological factors. The mean range of Alexandria tide is 17.56 cm which is approximately equal to 2/3 of the spring tide range, while the most pronounced tidal sea level range are between 20-25 cm. The greatest possible range of tidal sea level variation is 48.20 cm, it represents the largest possible variations in sea level due to the tide and meteorological conditions.

The mathematical relations show that the possible largest range of sea level variations due to meteorological conditions is nearly 2/3 of the largest range of tides. However, these results obtained from restricted amount of data and it opens the way for further research for long period.

REFERENCES

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