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STATISTICAL ANALYSIS OF DAILY SEA LEVEL IN ALEXANDRIA HARBOUR, EGYPT.

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ABSTRACT

The daily sea level changes at Alexandria are determined by statistically analyzing the changes in individual months for five years period (1977 - 1981). For describing these variations, the mathematical expectation (Mean, Variance, Skewness and Kurtosis) have been determined.

Estimates have been made of the frequency distributions to show the structure of daily sea level over monthly scale. The deviations of these distributions from the normal case were obtained by comparing them with those corresponding standard normal distributions.

The rate of daily sea level variations are determined and showed a considerable differences between summer and winter months. It also indicated that the increase in sea level from day to day is more than the decrease limits.

INTRODUCTION

A number of theoretical and observational studies have focused on variability of sea level heights and their fluctuations due to meteorological factors at Alexandria (Sharaf El Din, and Rifaat, 1968; Moursy, 1976; Rady, 1979 and Moursy, 1989). The study of the general pattern of these fluctuations has not been carried out before.

For daily mean sea level, exact descriptions of the general phenomena of the variations are impossible, because it depends on the range of the tide and the range of sea level variations caused by hydro-meteorological factors. Since these two factors follow quite different lows, so the study should be based on the statistics and probability theories.

The present paper is an attempt to illustrate the general picture of the probability distributions of daily sea levels at Alexandria by determining their moments, particularly the first four moments (Mean, Variance, Skewness and Kurtosis).

The useful way of describing the deviation in daily sea level due to external factors is to determine their standard normal distributions and comparing them with those observed frequency distributions, so as to obtain a better evaluation of the variations in sea level.

For practical purposes, the speed with which the changes in sea level may occur is of great interest. In this connection one day interval is chosen for the determination of the rate of sea level variations.

Data and Methods of Analysis

Daily mean sea levels for 5 years period (1977 - 1981) were obtained from hourly reading of tide gauge records, using Doodson' X_0 filter. The tide gauge is located in the inner part of the Western Harbour of Alexandria which is limited by (31:10-31:12N) and (29:50-29:53E).

Because of the irregular variations of daily sea level, the mathematical expectation (Mean, Variance, Skewness and Kurtosis) were used for determining the general picture of the distribution in individual months. The statistical theories applied in this study are extracted from the Probability and Statistics by Murray R. Spiegel, 1982.

RESULTS

Variations in sea level at Alexandria are fairly insignificant, but the character of these variations is however important for oceanographers, engineering and navigators. The daily variation in sea level changes by a few centimeters, this variation is irregular during the year, it therefore becomes desirable to analyze the sea level data statistically so as to obtain the general characteristics of the variations in daily sea level.

Mathematical expectation of daily sea level:

On basis of time series of daily sea level for 5 years period (1977-1981) the monthly average of sea level were calculated and given in table 1. The results show that the highest mean values usually occur in July and August, which is attributed to the lower atmospheric pressure during these months. It may also be noted that December and January gave high monthly mean which agree with the facts determined by Hamed, 1983 and Moursy, 1989, that the strong wind effect on sea level is mainly from the south westerly wind of winter season. On the otherhand, March, April and May show the lowest monthly mean because of the higher values of atmospheric pressure.

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Detailed knowledge of the expected daily sea level state can be seen in table 1 for the second moment (Standard deviations), this table shows that the largest deviations usually occur in winter months (December, January), while summer months (July, August, September) show low dispersion about the mean. However, the departure from the mean values varies widely from month to month, but still have its seasonal cycle.

Table (1): Monthly mean and standard deviations of daily sea level during the period (1977 - 1981).

Month	Mean(cm)	Standard deviation
Jan.	49.66	9.17
Feb.	44.45	7.95
Mar.	37.80	8.31
Apr.	39.58	6.25
May	39.45	5.05
Jun.	48.28	6.51
Jul.	55.70	3.80
Aug.	54.80	3.60
Sep.	49.80	3.17
Oct.	48.66	5.59
Nov.	47.77	6.72
Dec.	54.29	10.52

The maximum and minimum observed daily sea level for each month during the recorded period are given in tables 2 and 3. According to table 2, the major maximum daily sea levels recorded were always in December, which exceed 70 cm and reached 83.10 cm at 1980, while the minor one were usually in July and August.

Table (2): Maximum recorded daily mean sea level (cm) for each month of the period (1977 - 1981).

Month \ Year	1977	1978	1979	1980	1981
Jan.	51.80	66.10	73.20	69.60	72.90
Feb.	58.60	61.20	68.70	55.10	56.70
Mar.	56.50	58.50	46.80	57.70	53.20
Apr.	58.20	57.80	55.70	53.20	44.30
May	47.00	50.40	46.30	53.40	50.30
Jun.	64.30	56.20	60.10	56.90	51.00
Jul.	64.00	65.10	60.00	64 10	57.30
Aug.	63.70	63.80	60.00	63.30	57.00
Sep.	61.70	53.90	54.00	53.00	51.50
Oct.	58.50	56.00	56.50	65.00	51.90
Nov.	55.00	55.00	69.30	67.80	57.20
Dec.	82.80	75.40	76.70	83.10	70.10

Similar results were obtained by using table 3 for the minimum recorded daily sea levels. The major minimum were always in March and April, while minor one were in July and August, and occasionally in December.

Table (3): Minimum recorded daily mean sea level (cm) for each month of the period (1977 - 1981).

Month \Year	1977	1978	1979	1980	1981
Jan.	27.70	27.90	44.30	31.50	35.00
Feb.	32.40	38.50	24.00	29.50	28.50
Mar.	25.20	21.90	18.80	20.30	32.40
Apr.	31.00	35.00	27.00	26.90	29.90
May	30.30	32.20	30.10	30.80	28.60
Jun.	36.70	38.90	39.00	37.90	33.90
Jul.	53.10	47.70	49.00	51.50	43.90
Aug.	48.90	40.30	52.00	50.20	47.20
Sep.	38.00	45.00	43.60	46.30	40.60
Oct.	30.80	40.00	38.20	40.60	41.40
Nov.	35.00	26.00	45.50	32.10	38.20
Dec.	32.80	46.50	40.70	25.60	47.60

The above descriptions are given to provide background information about the general phenomena of daily sea level at Alexandria. There are unusual rises of daily sea level during storm conditions. Attention is focussed on the daily sea level resulting from a single storm during December of each year of the five years period. Table 4, shows the mean of daily sea level over the period of the storm surge, the standard deviations, the minimum and the maximum observed sea level, with the storm surge durations. It is noticed from this table that the daily sea level is always higher than the mean value (45.5 cm).

Table (4): Mean, Standard deviation, Minimum and Maximum daily sea level during some of storm surge days of December for (1977 - 1981).

Period	Day's No.	Mean	Stan. Dev.	Min.	Max.
Dec. 1, 1977	14	64.03	8.82	52.40	82.80
Dec. 1, 1978	17	62.58	5.77	52.80	75.40
Dec. 12, 1979	7	66.97	5.37	61.30	76.70
Dec. 9, 1980	9	47.15	20.05	27.0	83.10
Dec. 8, 1981	23	61.86	5.91	52.10	70.10

Moment coefficient of skewness of daily sea level for each month are given in table 5. It shows that the distribution skewed to the right in winter months and to the left in summer ones, which may be attributed to the wind direction during these seasons. However, the general distribution approaches to a symmetric (Normal distribution).

Table (5): Moment coefficient of skewness and kurtosis of daily sea level for the period (1977 - 1981).

Month	Skewness	kurtosis	Month	Skewness	kurtosis
Jan.	.17	3.05	Jul.	-.44	2.07
Feb.	.17	2.69	Aug.	-.05	2.82
Mar.	.34	2.88	Sep.	-.31	3.06
Apr.	.61	2.85	Oct.	.20	2.08
May	.17	2.53	Nov.	.07	2.67
Jun.	-.25	1.73	Dec.	.30	2.25

In addition, table 5 shows the moment coefficient of kurtosis. It reveals the general pattern of daily sea levels, where it seems to be normally distributed.

Frequency distribution of daily mean sea level

An important aspect of sea level study is to know its frequency within a certain range of amplitudes. Listizen, 1974, pointed out that the knowledge of the frequency is very important, since the tidal variations on the one hand and the hydro- meteorological increase and decrease in sea level on the otherhand show a very complex picture following quite different lows.

In order to find out the frequency distributions, the daily sea level were arranged in increasing order according to their levels and classified into groups with height interval 5 cm, then the number of cases for each interval was determined and expressed as a percentage of the total frequency. Example of these frequencies are presented graphically in figure 1a and 1b for 1981.

To show the deviation of these distributions from the standard case, it is desirable to compare them with those expected frequencies (Theoretical values) for the same period. In this case, we have to reduce all the frequency distributions to their essential nature, by regarding every distribution have a mean value zero and standard deviation equal to unity.

Standard normal form of the daily sea level distributions for each month of 1981 are illustrated in Fig.(1), which show the coincidence between the observed and calculated frequencies in most months of the year. while the deviations in the other months can be considered significant. The greatest observed deviations can be seen in winter months (November, December, January), which are

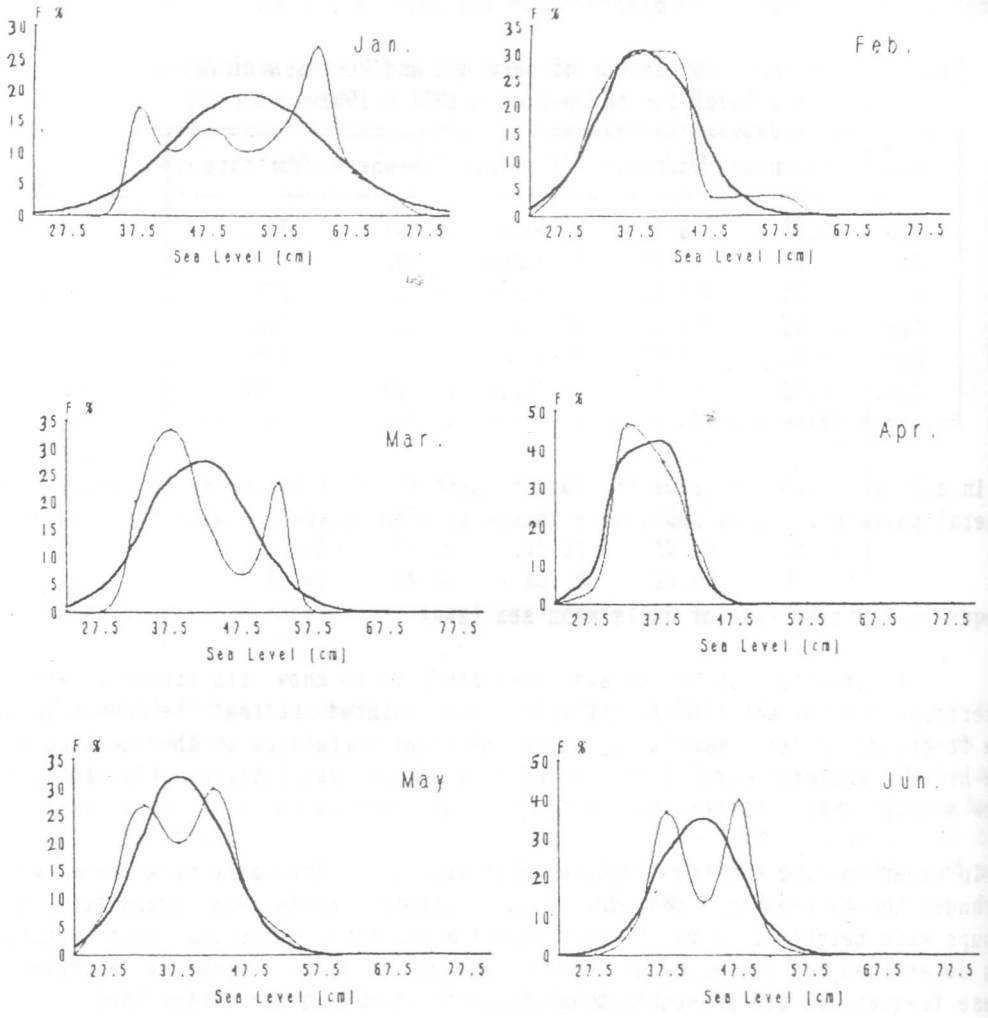

Figure 1(a): Recorded and expected frequency distribution of daily sea levelf or the months (Jan. to Jun. of 1981).

____ Expected frequency
____ Recorded frequency

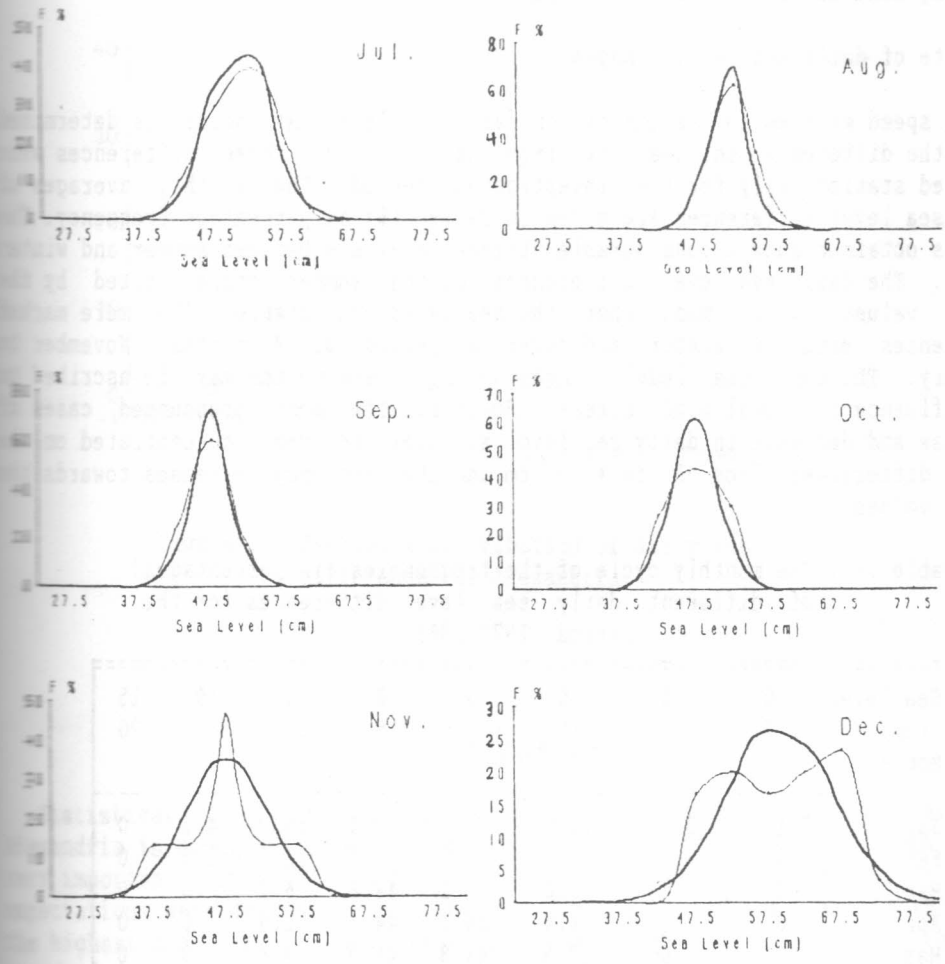

Figure 1(b): Recorded and expected frequency distribution of daily sea level for the months (Jal. to Dec. of 1981).

____ Expected frequency
____ Recorded frequency

attributed to the local effect of strong south westerly wind. The oscillation which has been noted during spring months (March, April, May) are due to changing wind direction during this season.

The rate of daily sea level changes

The speed with which the changes in daily sea level may occur is determined from the difference in sea level from day to day. These differences were analyzed statistically for the investigated period. The monthly averages of daily sea level differences are given in Table (6) as percentage frequency. The results obtained show a considerable difference exists between summer and winter months. The daily sea level differences during summer characterized by the lowest values, which means that the sea level are stable. The more marked differences occur in winter and cover a period of 4 months, November to February. The rapid sea level changes during these months may be ascribed to the influence of local wind stress. However, the most pronounced cases of increase and decrease in daily sea level all over the year concentrated on the height differences from -5 to + 5 cm and the frequency decreases towards the higher values.

Table (6): The monthly cycle of the frequencies (in percentages) of different daily sea level differences for the period (1977-1981)

Sea level (cm) / Month	-20 -15	-15 -10	-10 -5	-5 0	0 5	5 10	10 15	15 20
Jan.	2.1	3.4	11.0	33.1	30.3	15.9	4.1	0
Feb.	0	3.1	7.7	36.1	39.2	12.3	1.5	0
Mar.	0	.7	11.0	37.2	44.8	6.2	0	0
Apr.	0	2.1	6.4	34.3	44.3	12.9	0	0
May	0	0	3.5	44.8	46.9	4.8	0	0
Jun.	0	0	4.1	52.4	42.1	1.4	0	0
Jul.	0	0	1.4	45.7	52.9	0	0	0
Aug.	0	0	0	32.4	67.6	0	0	0
Sep.	0	0	0	43.5	54.5	2.1	0	0
Oct.	0	0	3.5	37.9	56.9	1.7	0	0
Nov.	0	.7	6.5	40.2	46.2	5.7	.7	0
Dec.	.7	2.8	17.2	22.1	38.6	13.8	2.8	1.4

The annual frequency of daily sea level differences reproduced by Fig. (2) shows the varying character of the changes in daily sea level at Alexandria. Almost 85% of these variations occur within the limit of -5 to + 5 cm. It may be mentioned that while the frequency is approximately 47 % in the height differences from 0 to 5 cm, it is only 38 % in the height differences from 0 to -5 cm, which means that the increase in sea level from day to day is more than the decrease limits.

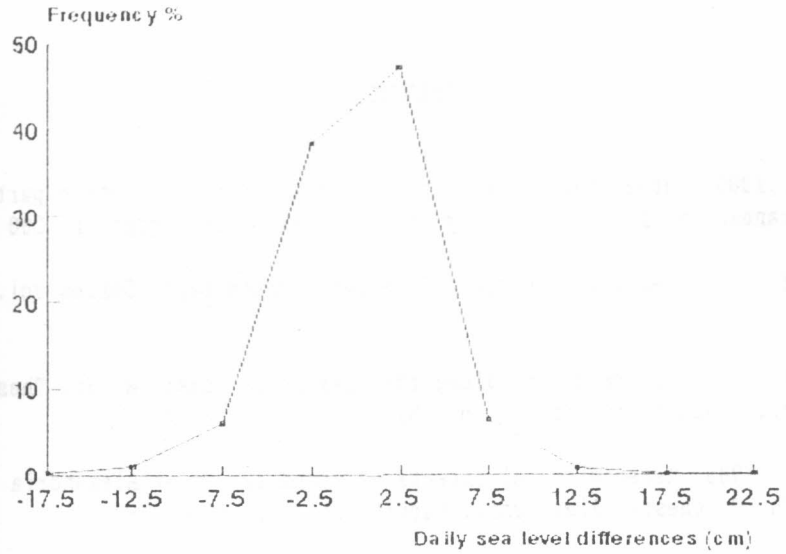

Figure 2: Frequency distribution of daily sea level differences at Alexandria.

CONCLUSIONS

Statistical analysis has been applied to the daily mean sea level at Alexandria in order to estimate probability models of these distributions. A very important concept in this probability is the expected values. These expectations were determined over individual months, and the results show that the highest mean values were often found in July and August, with very low standard deviation, while the high values due to storm conditions were in December with high standard deviation. On the otherhand, March, April and May gave lowest monthly mean.

Higher moments of the expectation (Skewness, Kurtosis) show that the daily sea level distribution approaches a symmetric and seems to be almost near the normal distribution. The deviation of these distributions from the standard form can be considered significant in winter months.

The frequency distribution of the daily mean sea level shows that it is normally distributed with some deviations during winter months.

The speed of the changes in sea level from day to day during winter months is more than summer ones. Almost 85 % of the daily height difference occur within the limit of -5 to +5 cm. The frequency show that the increase in sea level from day to day is approximately 47 % while the decrease is only 38 %.

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