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STORM SURGE GENERATION BY WINTER CYCLONES AT ALEXANDRIA, EGYPT

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Abstract

The storm surges generated by winter cyclones in the Eastern Mediterranean, at Alexandria coast, are classified according to the synoptic situations. The data used are the hourly sea level values in the western harbour of Alexandria, the atmospheric pressure and the wind velocity at a station nearby the tide gauge during storm periods, from 1971 to 1984.

Five types of storm surges were identified. Type A represents the weak surge case with a maximum residual of the order of 12-18 cm. Type B has a maximum residual between 20 and 24 cm. Type C is a moderate surge with an average maximum residual (26-30 cm). Type D has a strong surge, between 35 and 38 cm. Finally, type E has the strongest surge, reaching 43 cm. The depression tracks associated with each type are presented and the observed surges are compared with calculated ones using an equation given by HAMED (1983). A reasonable agreement, with a standard deviation $\pm$ 5 cm, was found between observations and calculations.

Introduction

The prevailing wind over the Egyptian Mediterranean coast is mainly from south-west to north-west. This pattern is due to winter cyclones. At Alexandria coastal area, where the tidal range is small (about 30 cm), the shear stress generated by wind at the sea surface has a major role. The most important surges along the Egyptian coasts are generated when deep depressions progress towards the east of the Mediterranean (HAMED, 1983).

The main objective of this paper is to classify storm surges according to their heights and the associated synoptic situations during the winter season (Decem-

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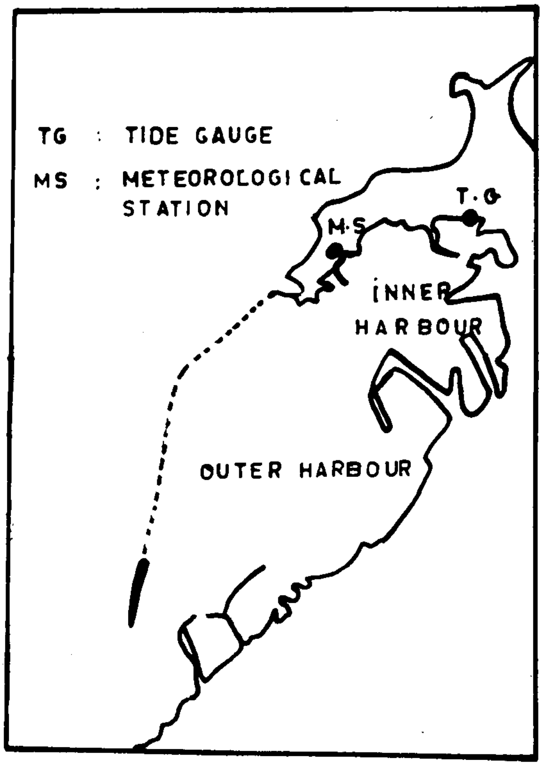


FIG. 1.— Map showing the positions of Alexandria tide gauge and the meteorological station.

ber, January and February), in the period from 1971 to 1984. This study is useful in the coastal engineering problems and the prediction of sea level variations.

Data and methods of analysis

The hourly values of sea level during storms were taken from the tide gauge records of the Western Harbour (Alexandria) Authority. The position of the tide gauge is shown in figure 1. The hourly values of the atmospheric pressure and wind velocity, in the same periods, were taken at Ras El-Tin meteorological station, which is near the tide gauge (fig. 1).

The hourly surge was calculated by subtracting the predicted tidal heights (*Admiralty Tide Tables*, Vol. II) from the recorded sea level, as well as by the low-pass filter.

These residuals will be related to wind velocity and the depression's movement and, therefore, they will be classified according to their strength and evolution. The frequency of each type will also be determined.

The observed surge will be compared with values calculated by an empirical relation, as a function of atmospheric pressure and wind speed at Ras El-Tin station, given by HAMED (1983) as follows:

$$R = -328.51 + 3.04\,V - 0.05\,V^2 + 0.31\,P \tag{1}$$

where R = residual height (cm)
V = wind speed (knots)
P = atmospheric pressure (mb).

Classification of storm surges at Alexandria coast

The storm surges at Alexandria coast are classified, according to their strength and evolution with time, into five types.

1 — Type A

This type represents a weak surge case with a maximum residual between 12 and 18 cm. The surge is lowered, at the beginning of the storm, and then raised. In this case, the surge has a small contribution to sea level changes. Figure 2(b) represents this type, which occurs when the center of the depression is passing far from the Egyptian coast (fig. 2(a)) (HAMED, 1983). The maximum wind speed is about 25 knots and the minimum atmospheric pressure is nearly 1008 mb. Generally this type stays about 2-3 days.

2 — Type B

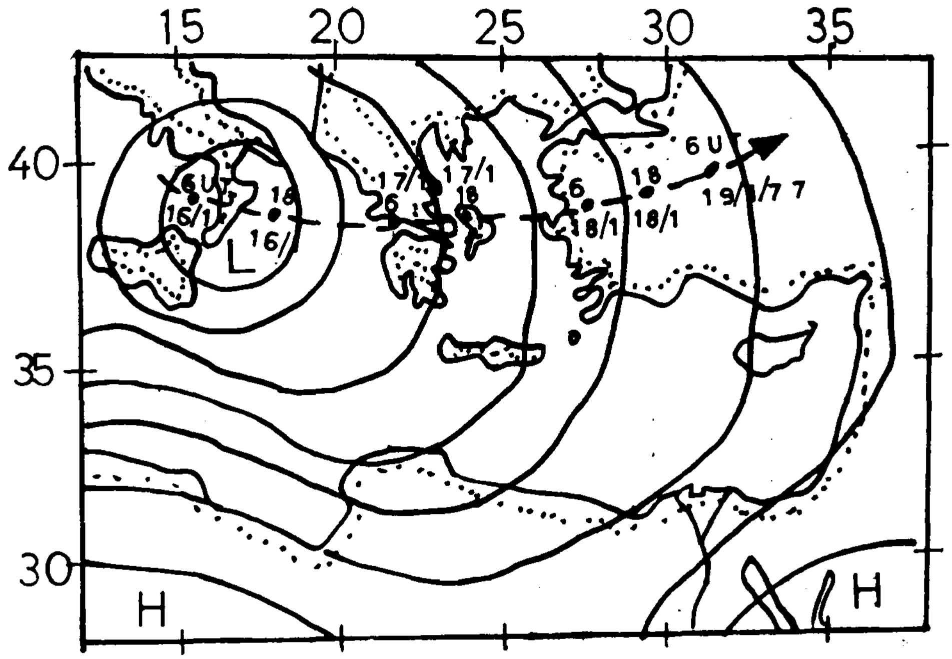
It is also a weak surge with a maximum residual (20-24 cm). In this type, the surge is increasing to reach the maximum at the storm peak, while the depression is moving towards Asia Minor (fig. 3(a) & (b)) (HAMED, 1983). In this case the surge has an important contribution to the sea level. The wind speed during that storm does not exceed 29 knots, the minimum atmospheric pressure is about 1012 mb and surge peak occurs when the depression center is near the Aegean Sea. It persists for 3-4 days.

3 — Type C

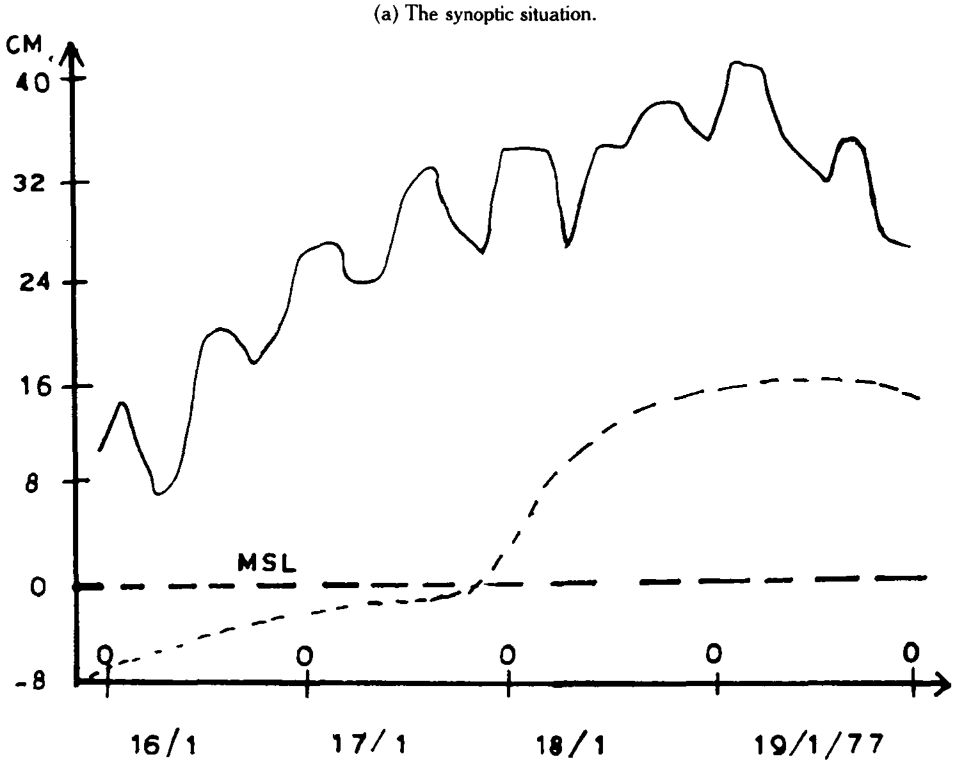
It is a moderate storm surge with an average maximum residual (26-30 cm). In this case the sea level is raising during the movement of the depression eastward via Crete (fig. 4(a) & (b)) (HAMED, 1983), and the surge constitutes the major part of the sea level changes. The wind speed may exceed 29 knots and the pressure reaches 1005 mb. The maximum residual occurs when the depression location is near the area of Crete. It persists at Alexandria for 3-5 days.

4 — Type D

This type has a strong surge (35-38 cm), and it occurs when the center of the depression, whose pressure reaches 1004 mb, is passing eastward near the

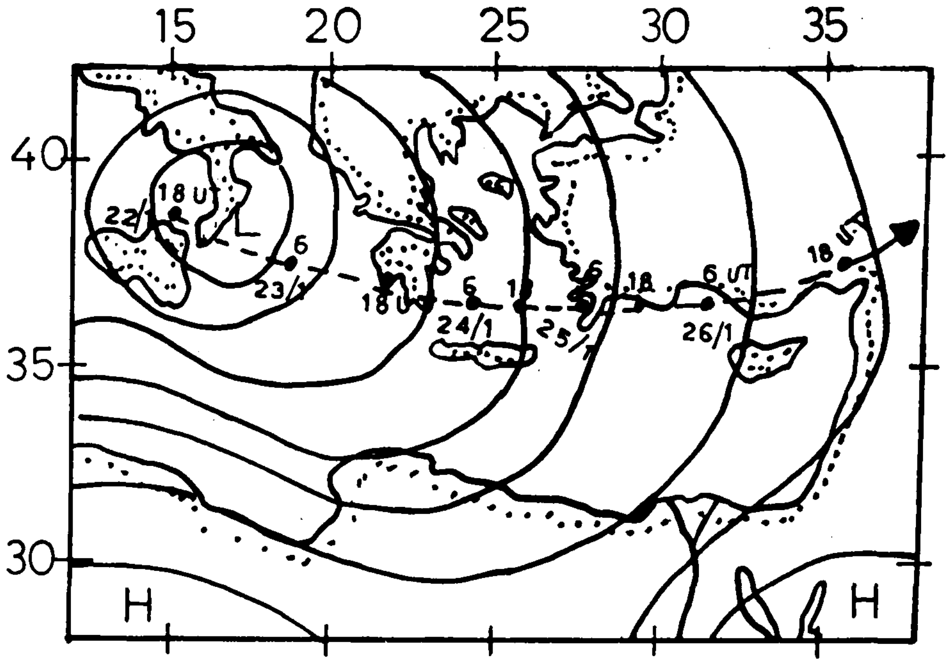


(a) The synoptic situation.

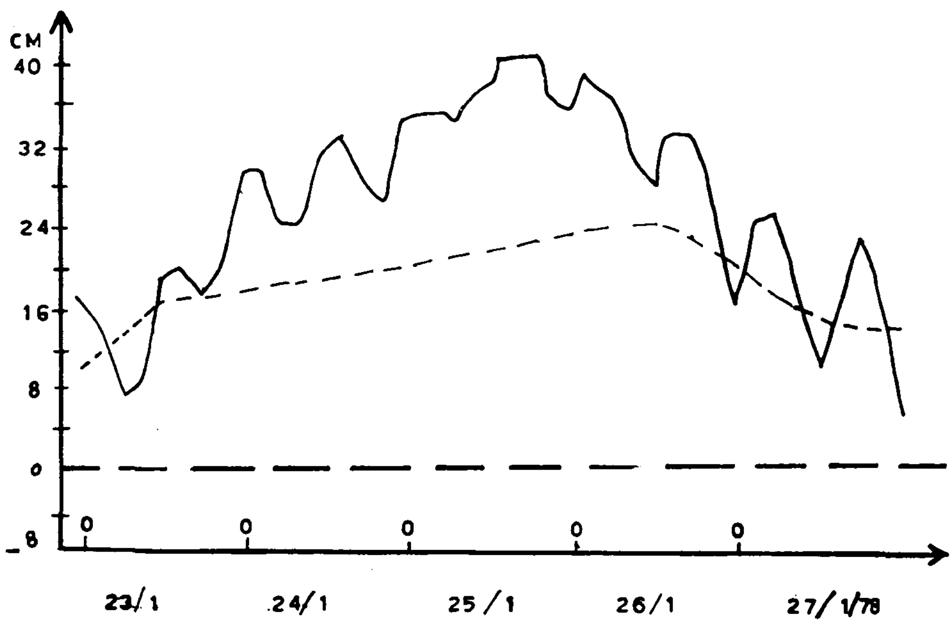


(b) The surge (———) and the recorded sea level (————).

FIG. 2.— Type A storm surge in the western harbour of Alexandria. HAMED (1983).

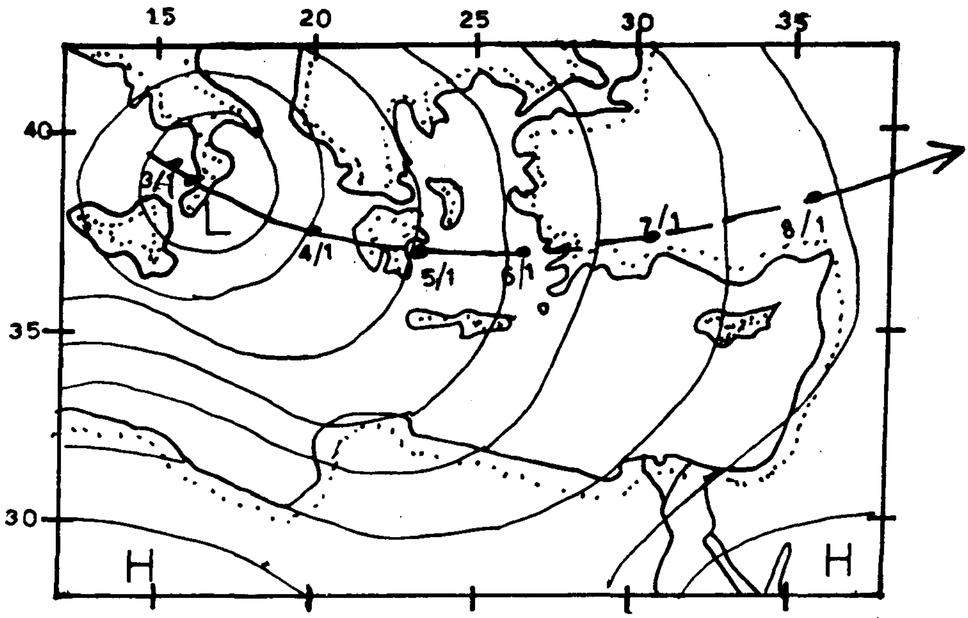


(a) The synoptic situation.

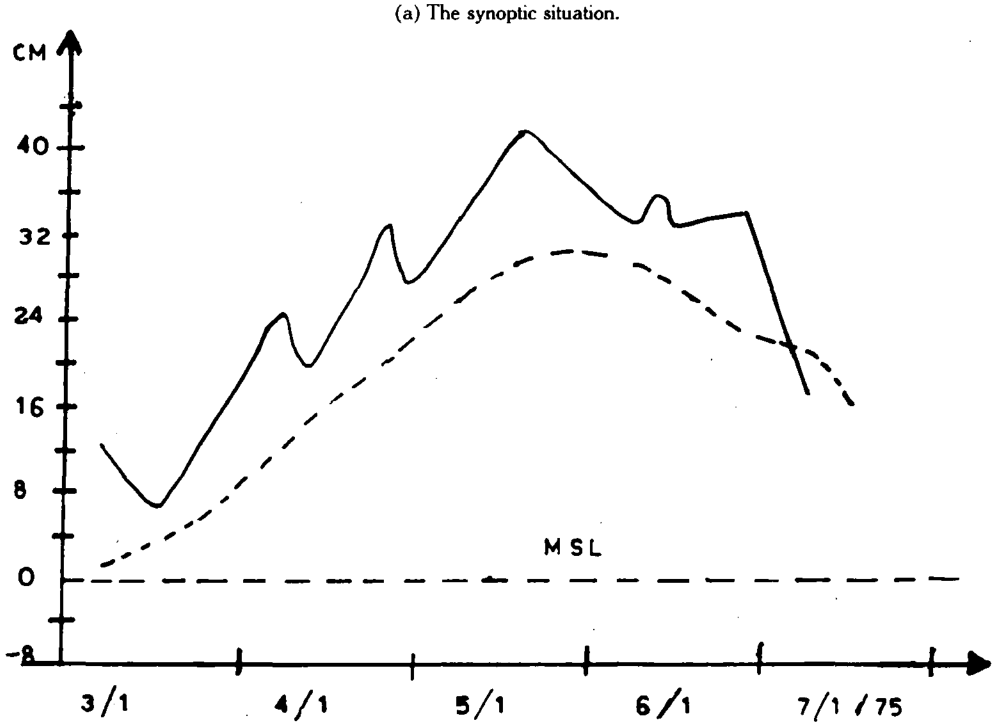


(b) The surge (– – –) and the recorded sea level (———).

FIG. 3.— Type B storm surge in the western harbour of Alexandria. HAMED (1983).



(a) The synoptic situation.



(b) The surge (— — —) and the recorded level (————).

FIG. 4.— Type C storm surge in the western harbour of Alexandria. HAMED (1983).

northern Egyptian coast (fig. 5(a) & (b)). In this case, the major sea level changes are due to meteorological effects. The wind speed reaches 30 knots with gusts sometimes reaching 60 knots. This surge stays about 3-6 days.

5 — Type E

This type has the strongest surge at Alexandria (about 43 cm). It occurs when the center of the depression passes near the northern Egyptian coast towards Cyprus (fig. 6(a) & (b)) where it stays about 24 hours. As in type D, this surge plays a significant role on the sea level changes. The occurrence of this type is associated with wind speeds up to 35 knots with gusts of 61 knots and the pressure is lowered to 1002 mb.

Frequencies of the storm surge types at Alexandria

The frequencies of the different storm surge types at Alexandria during winter (December, January and February), in the period from 1971 to 1984, are shown in table 1.

Table 1

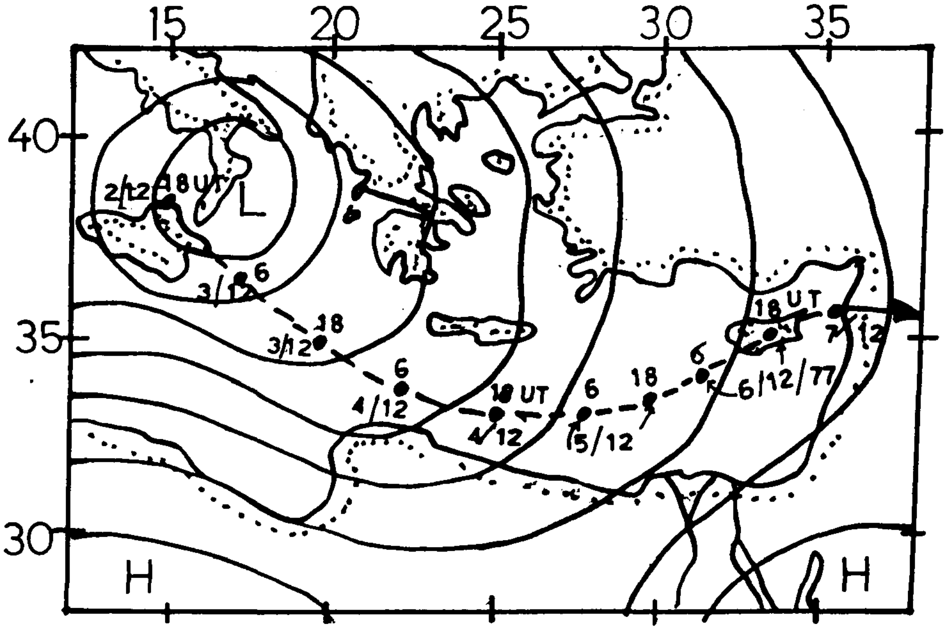
Frequencies of occurrence of different storm surge types

Month \ Type	A	B	C	D	E	Total
December	12	18	32	9	2	73
January	15	14	36	15	8	88
February	8	7	6	2	—	23
Total	35	39	74	26	10	184

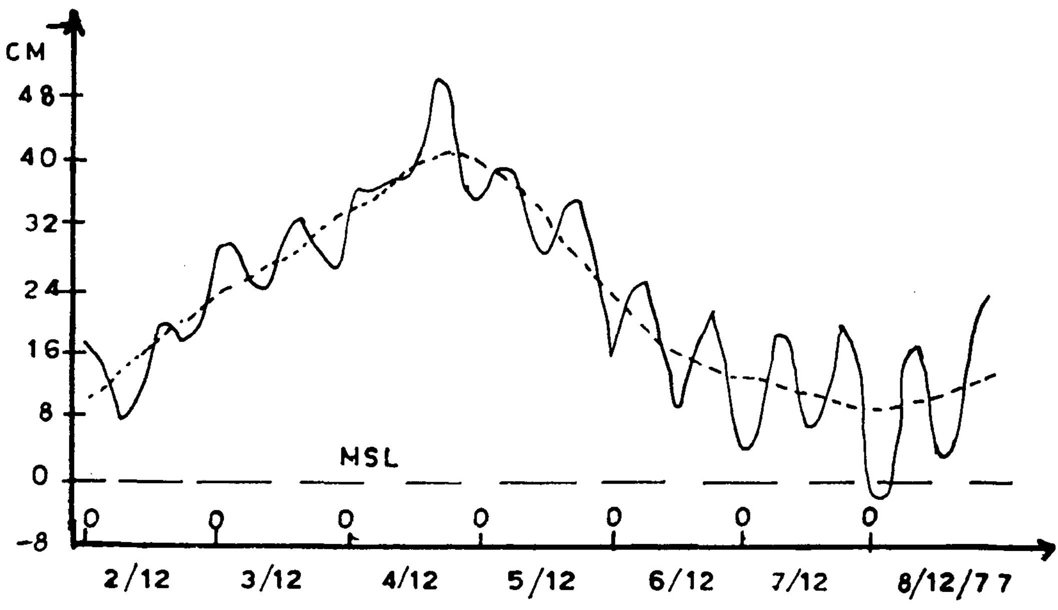
From table 1 it can be concluded that January has the highest frequency of storm surge as well as the most frequent occurrence of the most damaging surge of type E. On the other hand, type C is the most frequent one in winter.

Comparison between observed and calculated surges

In 1983, HAMED found an empirical formula to calculate the surge from the meteorological elements: pressure and wind speed (equation (1)). Storms, not included in the regression equation, are used to validate this formula. Figure 7 shows the relation between the observed and calculated surges, with a dotted line having a slope equal to 1. The standard deviation between observed and calculated values is $\pm$ 5 cm, which is a relatively wide range. The weak surge

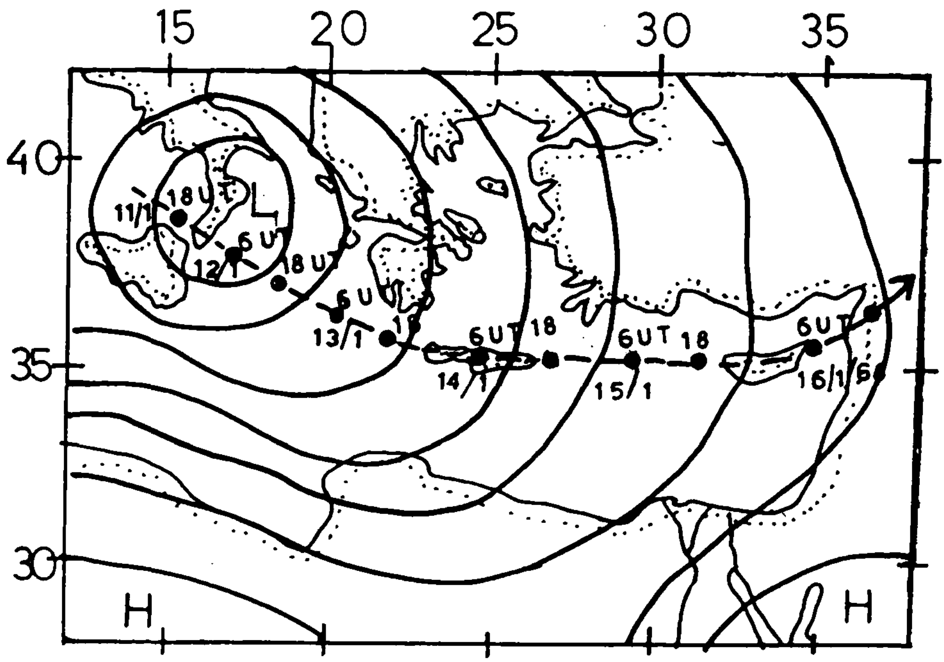


(a) The synoptic situation.

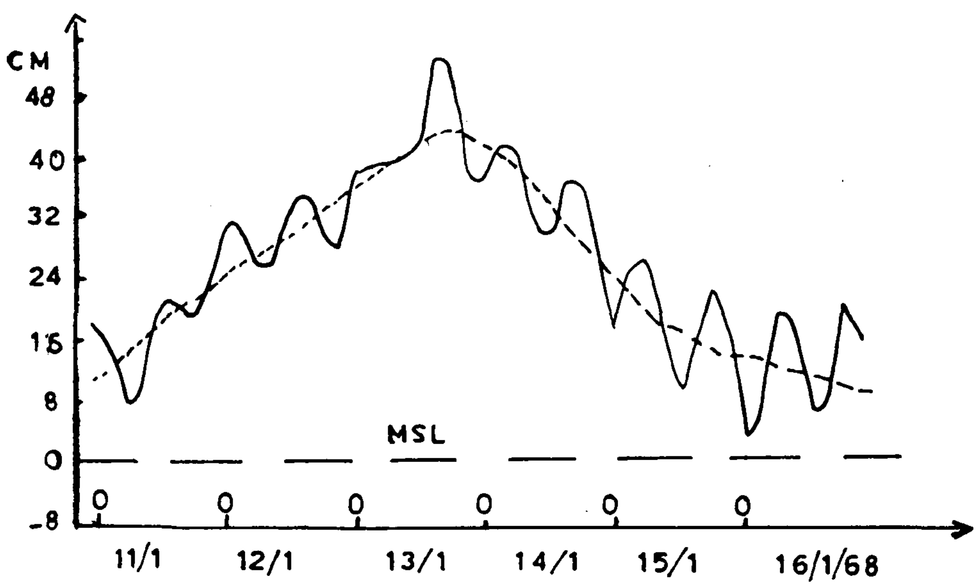


(b) The surge (———) and the recorded sea level (————).

FIG. 5.— Type D storm surge in the western harbour of Alexandria. HAMED (1983).



(a) The synoptic situation.



(b) The surge (———) and the recorded sea level (————).

FIG. 6.— Type E storm surge in the western harbour of Alexandria. HAMED (1983).

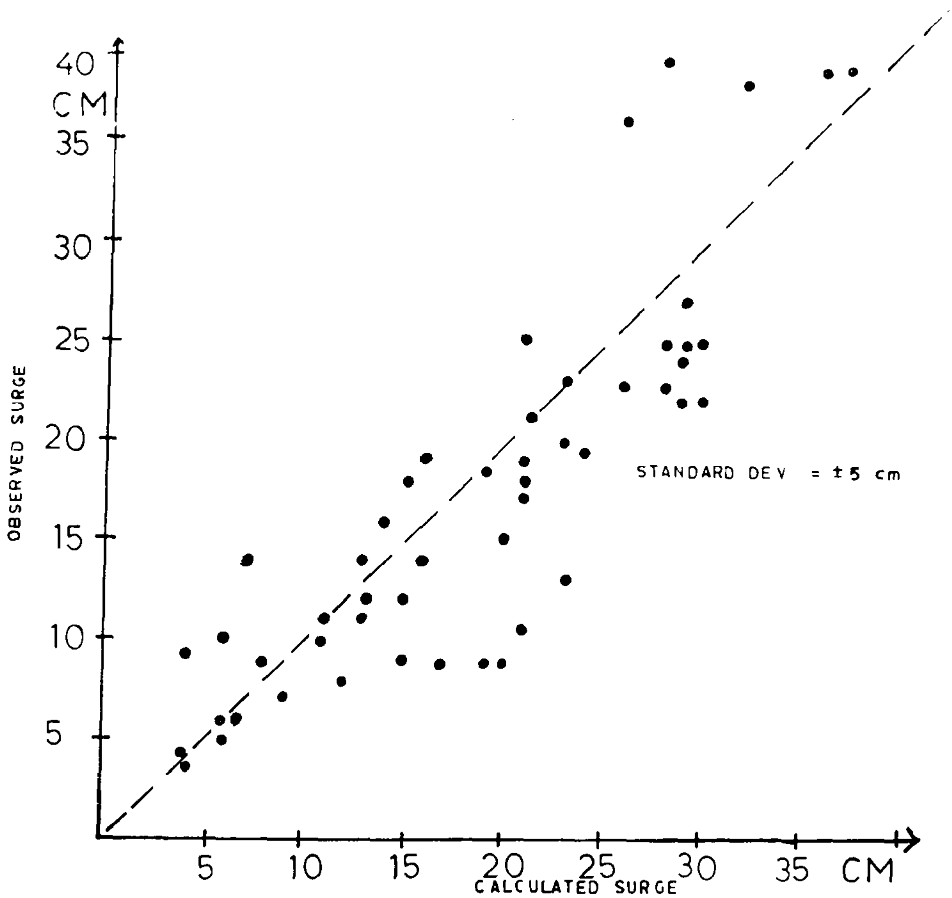


FIG. 7.— The relation between the observed surge and a surge estimated using HAMED equation (1983) including atmospheric pressure and wind speed, in the western harbour of Alexandria.

(up to 30 cm) is overestimated, while the stronger surge is underestimated. To get more reliable estimates, the wind direction and duration might be considered in the prediction nomogram. This will be discussed in a future work.

Summary and conclusions

Storm surges are classified, according to the strength and synoptic situation, into five types. The most damaging type has an amplitude of 43 cm and it often occurs in January, while the most frequent type in winter is type C with surge reaching an amplitude of 30 cm. Although a reasonable agreement is found between observed surge and calculations using HAMED's relation (1983), it is recommended to extend the studies for storm surge prediction considering wind direction and duration.

Reference

HAMED, A.A. (1983): Atmospheric circulation over the south eastern part of the Mediterranean. Ph.Sc. thesis, submitted at the Faculty of Science, Alexandria University, Egypt.