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Numerical Wave Hindcasting in the Eastern Mediterranean. A Case Study for the Storm of 10–11 December 1980

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Abstract
A comparison between measured and computed wave parameters (significant height and spectral peak period) is presented for the heavy storm in the eastern Mediterranean of mid-December 1980. It is hoped that the satisfactory results obtained will encourage the use of numerical models for wave forecasting in the eastern basin of the Mediterranean.

Introduction

In an earlier paper by Stiassnie (1978), which in the following text will be referred to as S1, satisfactory correlation was shown between observed and hindcasted wave parameters for the storm of mid-January 1968. The goal of S1, as well as that of the present paper, is to point out the applicability of spectral wave forecasting methods for the eastern Mediterranean.

The difference between the present paper and S1 is in the sophistication of the methods used, and it seems to reflect the general attitude of the Israeli official authorities with respect to marine sciences. The wave hindcasting technique utilized in S1 is the one described by Pierson et al. (1971). It is designed to be carried out manually, and it relies mainly on personal experience. The wave hindcasting results described here are based on the numerical solution of the wave energy balance equation. Moreover, the field measurements used in S1 in order to assess the validity of the forecasting technique were based on eye observations, whereas those used here were obtained from an advanced waverider buoy.

The heavy storm of 10–11 December 1980, which caused considerable damage along the Israeli coast, was chosen to exemplify the capability of the numerical wave-forecasting model.

The Numerical Model

The processes of wave generation, propagation and decay are formulated by means of the radiative

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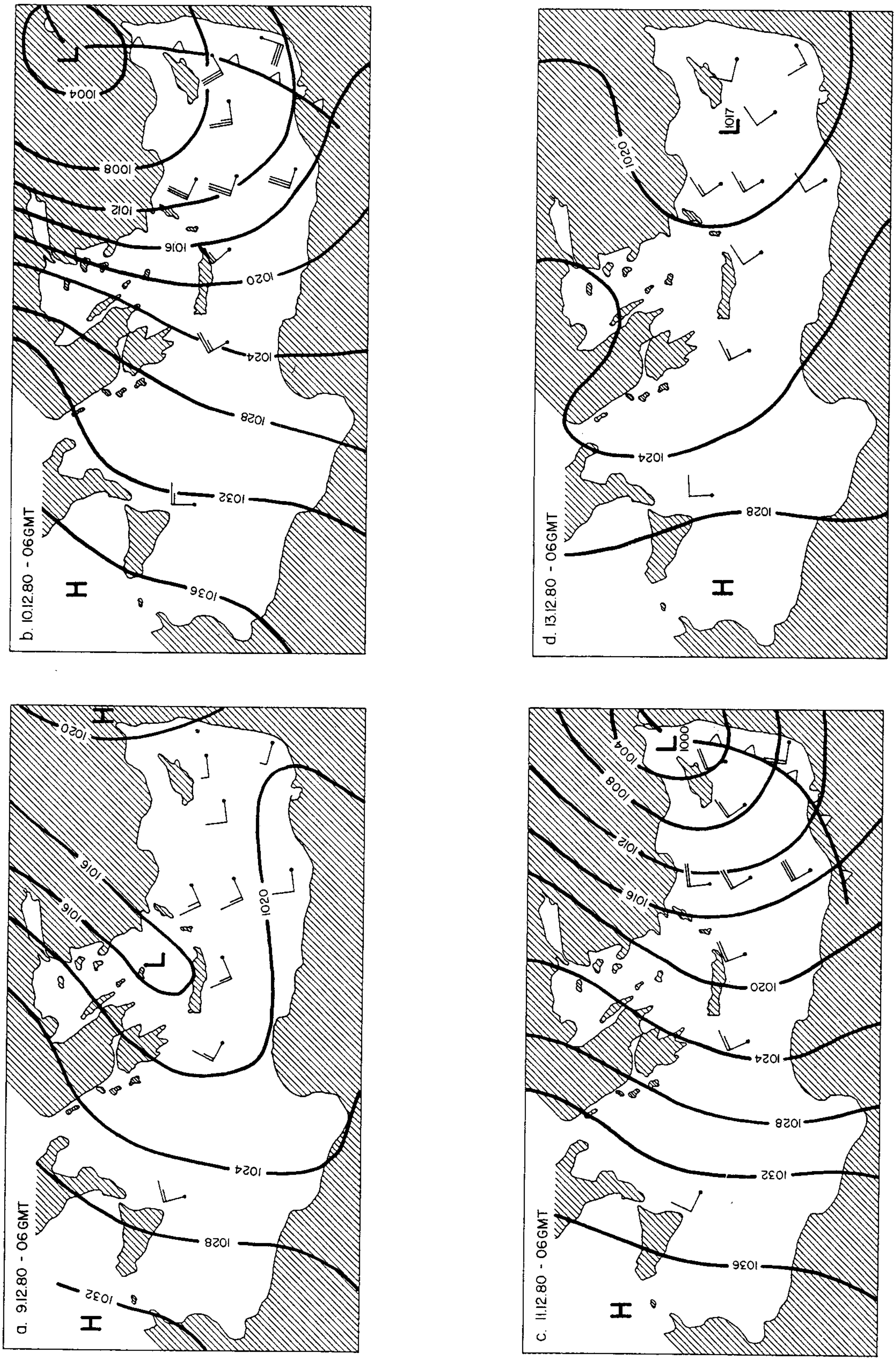
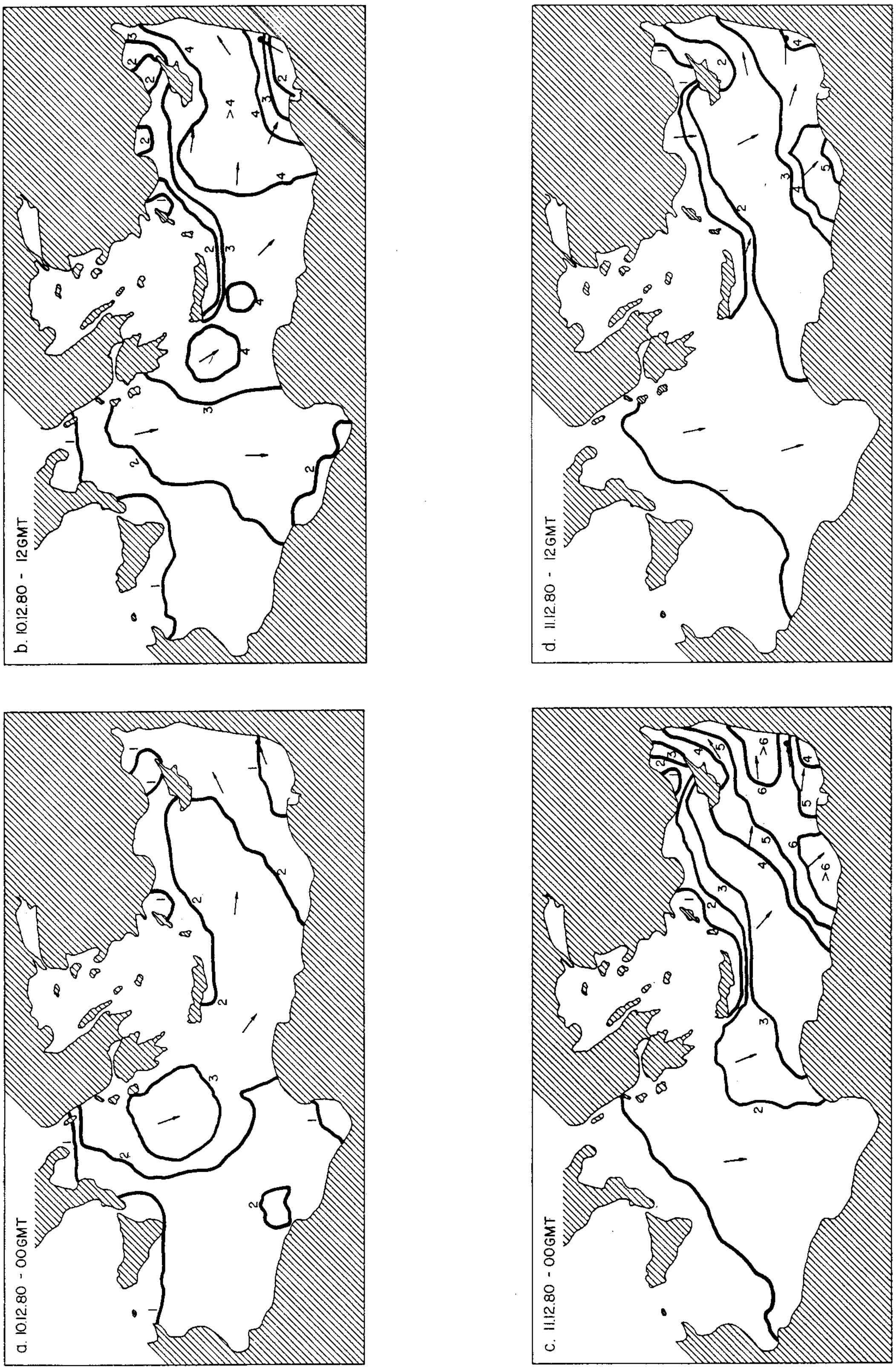


Fig. 1. The meteorological situation in the eastern Mediterranean for the storm of mid-December 1980.


a. 10.12.80 - 00GMT
b. 10.12.80 - 12GMT
c. 11.12.80 - 00GMT
d. 11.12.80 - 12GMT

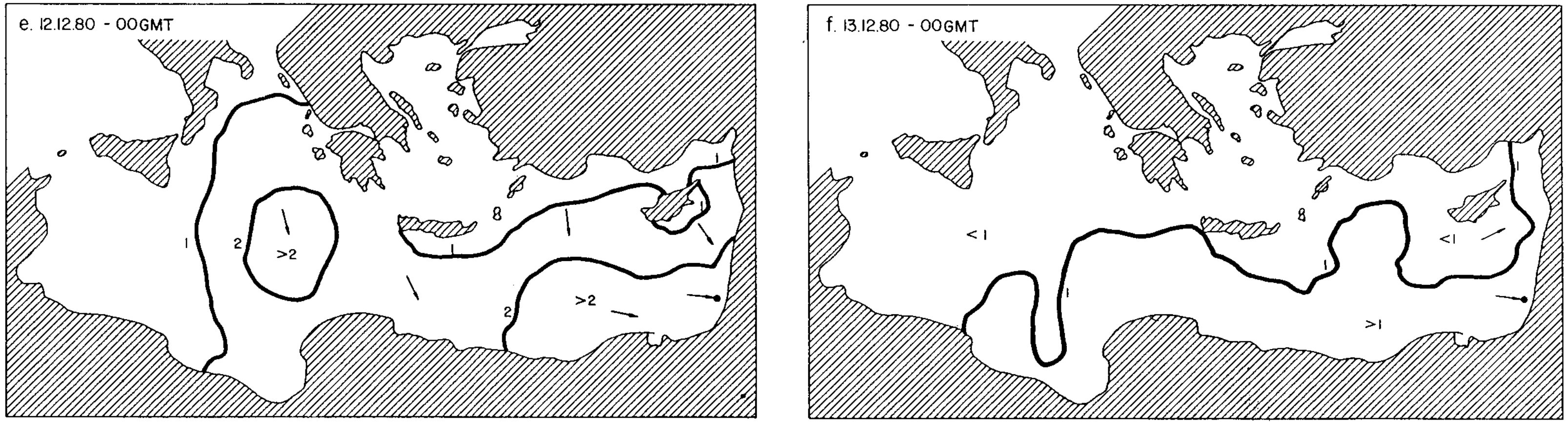


Fig. 2. Isolines of hindcasted significant wave height in the eastern Mediterranean for the storm of mid-December 1980.

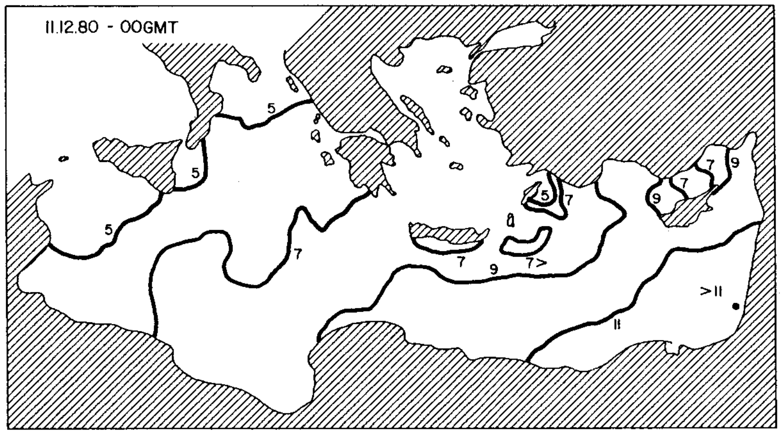


Fig. 3. Isolines of the spectral peak period in the eastern Mediterranean on 11.XII.80, 00 GMT.

transfer equation (Barnett and Kenyon, 1975). This equation describes the energy balance of the wind wave field in terms of the wave energy spectrum. In spite of being classified as linear hyperbolic, the radiative transfer equation has to be solved by a quite elaborate numerical technique.

Some of the important features of the present numerical model for wave forecasting in the eastern Mediterranean are as follows:

i) The two-dimensional energy spectrum is represented by 120 discrete wave trains. Each wave train moves in one of 12 possible directions, and has one of 10 possible group velocities. These velocities correspond to wave periods in the range between 4 and 21 s.

ii) Zero energy inflow from the few and carefully selected open boundaries, and complete energy absorption on the coasts (no reflection), are assumed. Note that the somewhat artificial assumption of zero energy inflow from the open boundaries influences the quality of the results only at very restricted areas (i.e Golfe de Gabès).

iii) The wind input has to be specified every 3 h at 23 different points scattered over the whole domain of the model.

iv) The basin of the eastern Mediterranean is covered by a rectangular grid consisting of 350 points, 60 km apart. The time step used in computation is 1 h. These values for the grid-spacing and time-step are the outcome of a numerical optimization.

v) A 12-point interpolation scheme is used for the convective term of the radiative transfer equation, in order to keep the numerical dispersion within reasonably low limits.

vi) The computation of one time step for the whole domain takes about 10 CPU-seconds on an IBM 370/168 computer. The required computer memory is 512 KB.

A detailed description of the mathematical and numerical model is given in Stiassnie and Bachu (1981). A somewhat similar method is outlined by Resio et al. (1978).

Meteorological Data

The input required for the numerical model consists of wind-data (intensity and direction) every 3 h at 23 specified locations.

Regarding the heavy storm of 10–11 December 1980, it was decided to run the model for the period from 9.XII.80 00 GMT to 13.XII.80 00 GMT. The meteorological situation during these four days is presented in four synoptic surface pressure maps, see Fig. 1a–d. From these maps, one can see the rather moderate winds (less than 15 knots) on the first and last days, and the much stronger winds (up to 30 knots) during 10 and 11 December. Thus, the 4-day period covers the full storm history, starting from its beginning as a very weak low barometric pressure north of Crete, through its peak as a deep low barometric pressure north-east of Cyprus with a cold front to Egypt, and on to its very end.

The wind data were deduced from these maps by an experienced meteorologist, using standard procedures based on the spacing between adjacent isobars.

Hindcasting Results

The hindcasted significant wave height is shown in Fig. 2a–f. The wave regime over the entire east Mediterranean basin is represented by lines of equal wave height (in meters), and small arrows indicating the dominant direction of wave propagation. The highest waves, more than 6 m high, were obtained on the northern part of the Israeli and southern Lebanese coasts, as well as on the western Egyptian coast. It is important to note the significant differences in wave height at a given time, between different parts of the Israeli coast. These differences should be kept in mind when trying to apply the wave climate measured at one location to a more distant site. It is also interesting to mention the different trends during the storm. In the first part of the storm the waves on the northern coast of Israel were higher than those obtained along the southern coast, see Fig. 2a–c. This situation reversed during the second part of the storm, as shown in Fig. 2d–f. The above-mentioned phenomena, as well as the changes in the main wave direction, are probably connected with the passage of the cold-front and the eastward movement of the low pressure system.

To complete the wave field picture, the period of the spectral peak is shown in Fig. 3 as lines of equal period, at the time of the highest waves. Waves with peak periods higher than 11 s were computed.

Measurements Versus Hindcasting

In order to assess the reliability of any numerical model for wave forecasting, a comparison with data from field measurements has to be made. The data set used for the present study was obtained from a Datawell waverider buoy installed offshore Ashdod at

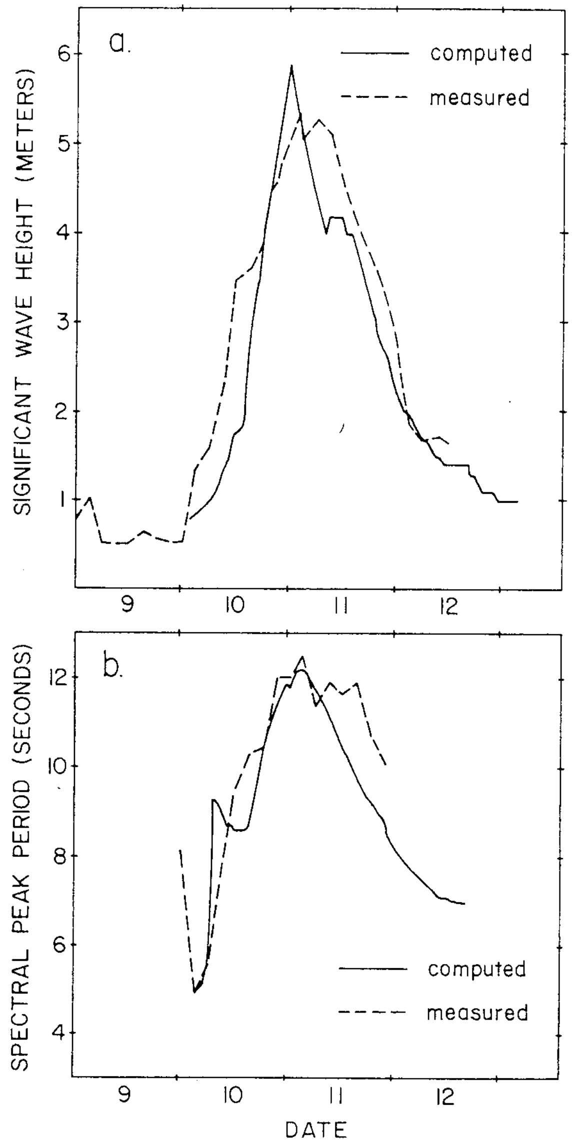


Fig. 4. Comparsion between computed and measured wave characteristics offshore Ashdod during the storm of mid-December 1980. (a) Significant wave height. (b) Spectral peak period.

20 m depth. The measurements and their analysis were carried out by the Coastal and Marine Engineering Research Institute, in cooperation with the Coast Study Division of the Israel Port Authority. A comparison between the computed and measured wave heights is shown in Fig. 4a, and for the spectral peak period in Fig. 4b. Apart from some time discrepancies (which are probably connected with the "warming up" of the model) the overall agreement is rather satisfactory. Results of similar quality were obtained for three other storms of different intensities. The agreement found in this study was obtained for wave hindcasting; an application of the model in a forecast mode would require forecasts of the wind as input. The accuracy of these wind forecasts will influence the quality of the wave prediction.

Conclusion

Good agreement between measured and numerically hindcasted wave characteristics in the east Mediterranean, was obtained for the heavy storm of mid-December 1980, as well as for other cases. This result, together with the possibility of obtaining very detailed information about the sea state in the whole basin, should encourage the daily application of numerical models for wave forecasting.

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