Wind wave Mixing in the Saronikos Gulf

by

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Abstract

The wave characteristics of each of twenty-five points in the Saronikos Gulf were computed using empirical formulas for fetch limited situations. The values demonstrate how the prevailing northerly winds generate much smaller waves and thus provide less surface mixing energy to the system. The percentages of a certain mixed depth occurring at the various localities are given, showing for example, how particular regions experience considerable wave mixing while others do not.

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Surface wave mixing is often neglected in the discussions of surface water properties. In situations where high surface gradients are apt to form, the phenomena of wind wave mixing must be considered.

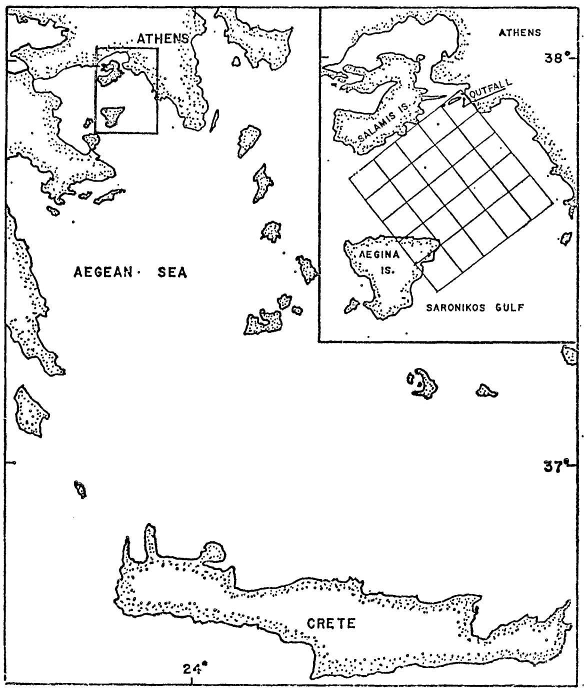


FIG. 1. — Saronikos Gulf fetch region and grid. The box centers were considered the grid points. Total grid is 20 km square.

Rapp. Comm. int. Mer Médit., **23**, 5, pp. 81-84, 3 figs (1976).

In the Saronikos Gulf large amounts of sewage effluent are discharged in the surface waters at the northern shore (Fig. 1). The manner in which this nutrient rich effluent enters the Saronikos Systems becomes critically important for its surface biological utilization [HOPKINS, 1973]. Winds from the north regardless of strength, will not have the fetch to generate waves of any mixing capacity within the outfall area; whereas southern winds have a long fetch exposure and will be increasingly important, with increasing strength and duration, in mixing down a surface plume.

The potential for wind wave mixing was estimated from the wave lengths of wind waves generated under various wind conditions. A grid of twenty five points was established within the Inner Gulf of the Saronikos (Fig. 1) from each grid point a fetch table was computed using the closest distance to land at every 2 points (22.5°) of the compass. For all the directions, except for a south-easterly band of ESE to S, the fetch was short averaging 17 km. To the southeast the fetch is unrestricted until the island of Crete 550 km distant. The significant wave characteristics for each grid point were calculated using the empirical relationships of BRETSCHNEIDER [1959] between fetch, wind speed, and wave period.

For other than southeasterlies the wind blows over a short fetch and the contours of iso-characteristics are parallel to the windward shore. If we take the mixing depth to be indicated by half the wave-length, than that portion of the Saronikos having more than a 15 km fetch would be mixed to 10-20 m depth for winds of 10-15 m/s (Table 1). The minimum duration for such a situation is on the order of several hours. For northerlies an afternoon maximum of 10 m/s for several hours is not uncommon, in which case the 15 m mixing depth contour would run east-west near the mouth of the Saronikos, and for an occasional 15 m/s northerly the 15 m contour would run east-west from the northern shore of Aegina Island.

A wind record taken from a mechanical self recording anemometer, placed 10 m above the sea surface in the outfall area, was examined for three of the months during 1973. The statistics (Table 2) illustrate the frequency of winds from different directions and their strengths. In all three months the northerlies prevail. Westerlies and southerlies are seen to occur only occasionally, but are of more importance in terms of mixing potential due to their extended fetch. From the outfall a southwesterly has just over 50 km fetch permitting mixing depths of 30 m for 15 m/s winds. On 26 February 1973, a southwesterly blew for 9 hrs at more than 11 m/s (3 consecutive hrs of which were at 14.5 m/s) generating conditions for mixing to 28 m.

Certainly the most important case concerns winds from the long fetch window from the south and southeast. From this direction even light winds of 5 m/s can cause mixing to 50 m and over. The minimum duration to generate these waves increased to 2 days (Table 1). Such a duration existed, for example for 2½ days from noon on 14 February, 1973 with an average speed of 5.3 m/s. Since the winds were measured at only the one location nothing is known about their consistency over the 550 km fetch to Crete.

To illustrate the spatial variation of wind mixing over the grid area, the half-wave lengths were calculated for all directions for each of the grid points. The results are shown in Figs. 2 and 3 as percentage contours. The situation of a 10 m/s wind and 20 m half-wave length is characterized by a higher frequency of mixing to the east of the grid due to contribution of the westerlies. At the higher wind speed of 15 m/s and longer half-wavelength of 30 m the most frequently mixed area is a north-south band through the grid area. The immediate outfall area is relatively exposed with a 30 % frequency for this situation.

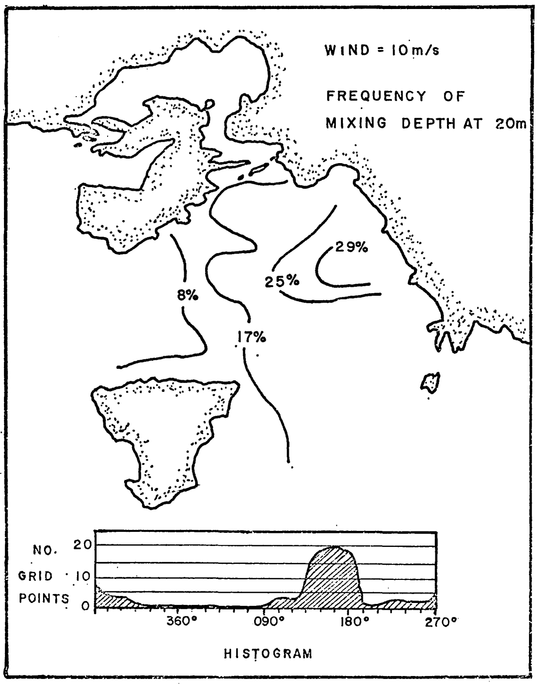
Since the winds are not evenly distributed in direction, these contours cannot be considered as probabilities of such mixing. It is clear, however, that areal exposure to wind mixing is quite uneven regardless of wind direction. The area between Salamis and Aegina Island is generally sheltered and that area in the center of the grid and to the east is generally exposed. The fact that the prevailing northerlies are ineffective in causing mixing through the grid area is not so significant as the frequency of southerly winds that might destroy gradients of water properties in the surface layer relative to the length of time it takes to re-establish these surface gradients.

Table 1

A. Short fetch Wind speed (m/s)	Fetch (km)	Period (sec)	Minimum duration (hrs)	Half wave length (m)
10	15	3.6	2	10
10	56	5.1	5	20
15	7.5	3.6	1	10
	28	5.1	2.5	20
	56	6.2	4	30
B. Long fetch				
5	550	2.5	44	50
10	550	9.1	29	65
15	550	11.3	23	100

Table 2

Period	*Speed*	*Direction (from)* North	East	South	West	*Total*
I. 3-27 February 1973 (600 hrs)	less than 5 m/s					38.3 %
	5-10 m/s	27.7 %	1.5 %	14.7 %	8.2 %	52.1 %
	10-15 m/s	4.6 %	0 %	2.5 %	2.3 %	9.4 %
	more than 15 m/s	0.2 %	0 %	0 %	0 %	0.2 %
II. 1-31 March 1973 (744 hrs)	less than 5 m/s					41.2 %
	5-10 m/s	36.8 %	3.9 %	4.4 %	5.7 %	50.8 %
	10-15 m/s	5.5 %	0.3 %	0 %	2.2 %	8.0 %
III. 8 August-5 September 1973 (696 hrs)	less than 5 m/s					15.8 %
	5-10 m/s	59.8 %	0.7 %	7.6 %	4.9 %	73.0 %
	10-15 m/s	7.6 %	0.6 %	0 %	2.3 %	10.5 %
	more than 15 m/s	0 %	0 %	0 %	0.7 %	0.7 %



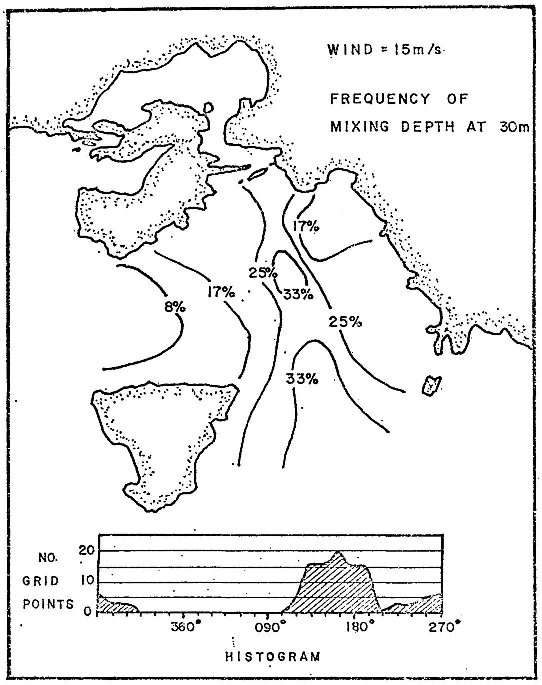


FIG. 2. — Frequency of wind mixing over 20 m with wind speed of 10 m s from all directions.
FIG. 3. — Frequency of wind mixing over 30 m with wind speed of 15 m s from all directions.

Acknowledgments

This work was supported by the National Science Foundation Grant GB 18568 and NATO SCOR Grant No. 3703. The authors wish to thank IBM Athens for use of their computer and the Institute of Oceanographic and Fisheries Research for the use of their facilities.

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