©2018 Published in 2ND International Symposium on
Natural Hazards and Disaster Management 04-06 MAY 2018 (ISHAD2018 Sakarya Turkey)

Contribution of Swells to Wave Climate along with the Southwestern Black Sea Coast

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Abstract

This study focusses on understanding contribution of swells to wave climate along with the south western coast of the Black Sea. For this, the simulated data from the nested SWAN model [1] at six locations off the south western coasts of the Black Sea for the period from 1979 to 2009 was used. To understand the dominant wave pattern in the study area, the wind sea and swell are classified based on the wave steepness expressed as the ratio between the significant wave height and the wave length (L = 1.56T2), where T is the mean wave period (Tm02). It is the same approach presented in [2]. Ocean waves are classified based on Hm0/L as sea, young swell, mature swell and old swell as suggested in [3]. According to the classification in both studies, locally generated waves or sea waves have steepness values greater than 0.025. Similarly, steepness less than 0.025 can be referred as swells. The swells are further classified as: old swells (Hm0/L < 0.004), mature swells (0.004 ≤ Hm0/L < 0.01) and young swells (0.01 ≤ Hm0/L < 0.025). The percentage of dominance of swells and seas for the different months and in different years of the study period is examined at locations considered. The results show that wind sea dominates along south western coasts. Towards the east percentages of the swells increase and they are significant. Swells even dominate at the location P3 selected in the west of Amasra. Towards the east dominance of wind seas increase again.

Key words: Sea waves, swells, wind sea, locally generated waves, Black Sea

1. Introduction

The waves at the ocean surface are the most obvious air -sea interaction phenomena at the interface between the atmosphere and the ocean. These wind waves (henceforth simple called waves) account for most of the energy carried by all waves at the ocean surface, and have a significant impact on coastal infrastructures, ship design and routing, coastal erosion and sediment transport, and are an important element in storm surges and flooding events. Two types of ocean waves can be identified at the ocean surface: wind sea and swell. Wind sea waves are waves under the influence of local winds. As waves propagate from their generation area, or when their phase speed is higher than the local wind speed, they are called swell. Swell waves can propagate thousands of kilometers across entire ocean basins [4-5].

Wind sea waves are more irregular and short crested, respond quickly to wind variations, and are characterized by a rather broad spectrum, while swell consists of rather regular long-crested waves whose evolution is not as strongly affected by wind. A swell spectrum is narrower, and as the wind drops or when waves leave the generation area, their steepness reduces sharply due to frequency-direction dispersion. From a more practical point of view, the energy of wind sea waves is

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contained at higher frequencies (i.e., between about 0.1 and 4 Hz) while swell waves have lower frequencies (i.e., between 0.03 and about 0.2 Hz) [6].

The nature of sea state is also identified based on the wave steepness (Hm0/L). The wave steepness is expressed as the ratio between the significant wave height and the wave length (L = 1.56T2), where T is the mean wave period of the peak period. The wind sea and swell are classified based on wave steepness to understand the dominant wave pattern in the study area. Thompson et al. [3] classified ocean waves based on (Hm0/L) as sea, young swell, mature swell and old swell. According to their classification, locally generated waves or sea waves have steepness values greater than 0.025. Similarly, steepness less than 0.025 can be referred as swells. The swells are further classified as: old swells (Hm0/L < 0.004), mature swells (0.004 ≤ Hm0/L < 0.01) and young swells (0.01 ≤ Hm0/L < 0.025) [2]. The present study examines the wind sea and swell characteristics based on the wave steepness using the simulated data from the nested SWAN model [1] at six locations off the south western coasts of the Black Sea for the period from 1979 to 2009 (Fig. 1). The coordinates of the locations are given in Table 1.

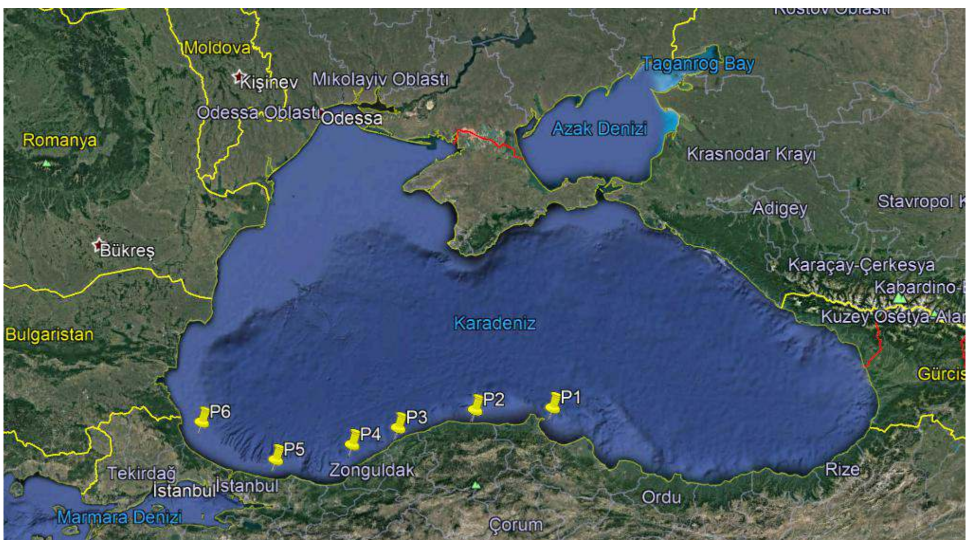

Figure 1. The locations selected in the south western coasts of the Black Sea for the analysis

Table 1. The coordinates of the locations focused on examining the wind sea and swell characteristics based on the wave steepness

Locations	Longitude (º E)	Latitude (º N)
P1	35.3	42
P2	33.8	42
P3	32.3	41.75
P4	31.4	41.5
P5	29.9	41.25

2. Results and Discussion

The percentage of dominance of swells and seas at different locations for the different months of the study period was shown in Figs. 2 and 3. The monthly percentage dominance of seas and swell for the study period from 1979 to 2009 was computed by proportioning the numbers of swell or wind sea waves throughout the working period to the total number for each month. Figs. 2 and 3 also show the dominance of the sea and swell waves for 31 years in all the data. The study shows that sea waves are dominant during the all period at P1. Their contribution is about 80% and swells have a contribution of about 20% at this location. At P2 and P4, swells (about 48%) have almost the same contribution as wind sea (about 52%). At P3, swells (51%) are predominant in total. The lowest percentage of the swells is observed at P6, it is almost 3%. At P2, wind sea are predominant during all months except for November and December where swells are dominant, but role of the swells are also significant. At P3, wind sea dominates in January and June. Even though wind seas are predominant during all months; the role of swell is also significant at P2 – P4. Dominance of swell is maximum (56%) during April at P3 and dominance of wind sea is maximum (99%) during August at P6. It is also noted that the wind sea dominance was high (between 80 and 100%) at P1, P5, and P6. Hence, the analysis clearly indicates the dominance of wind seas off south western coasts of the Black Sea.

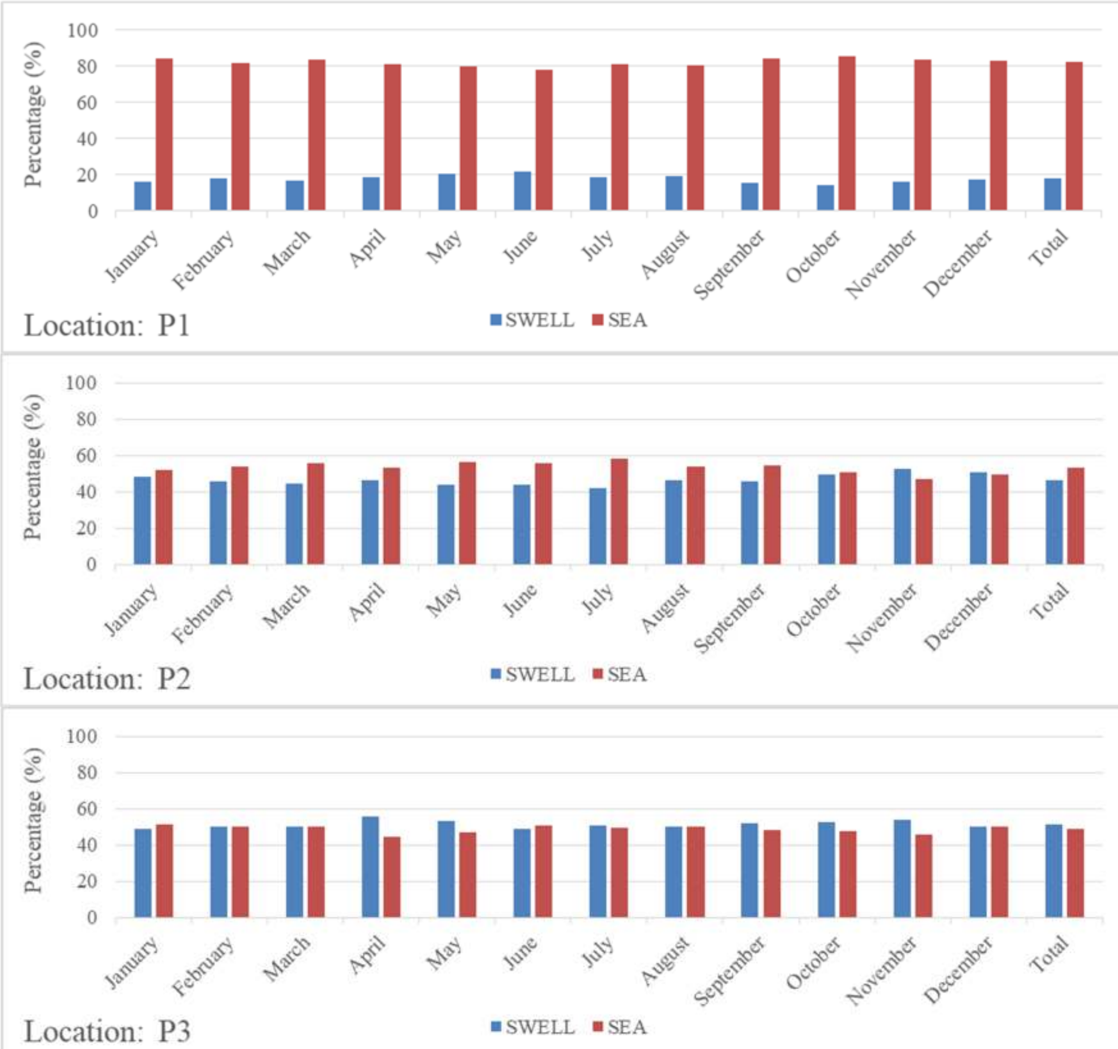

Figure 2. The percentage (%) of dominance of swells and seas at different locations (P1 – P3) for the different months of the study period

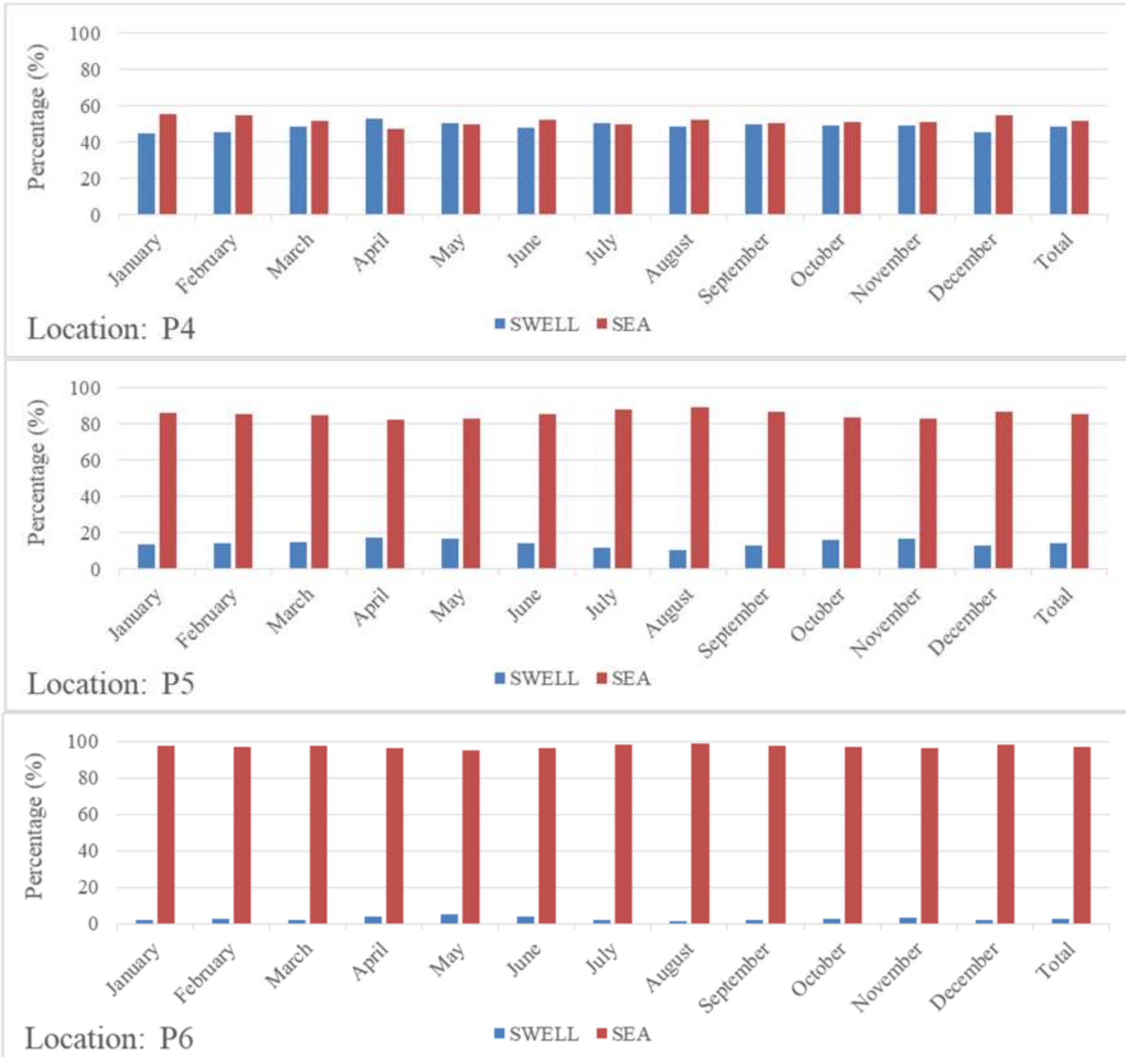

Figure 3. The percentage (%) of dominance of swells and seas at the locations P4 - P6 for the different months of the study period

The percentage of dominance of swells and seas at different locations for the different years of the study period was shown in Figs. 4 and 5. The yearly percentage dominance of seas and swell for the study period from 1979 to 2009 was computed by proportioning the numbers of swell or wind sea waves throughout the working period to the total number for each year. The study shows that dominance of the sea and swell waves at annual period has a similar characteristics as those at monthly period. The locations P1, P5, and P6 shows dominance of the wind sea during all years. At the locations P2 and P4, wind sea dominates in almost all of years but swells also are significant. The swells have an important contribution at P3 where wind sea is also significant.

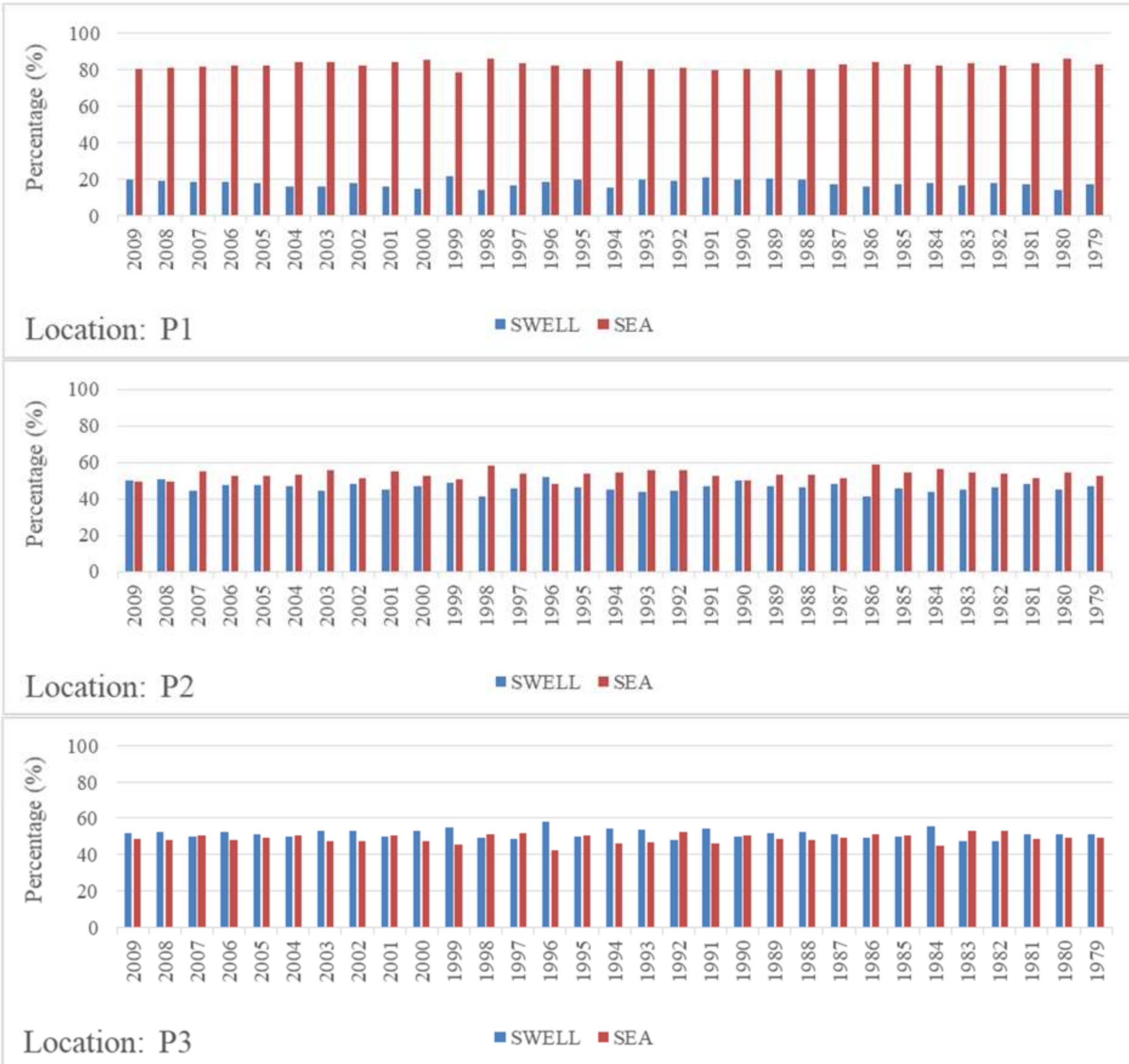

Figure 4. The percentage (%) of dominance of swells and seas at P1 – P3 for the different years of the study period

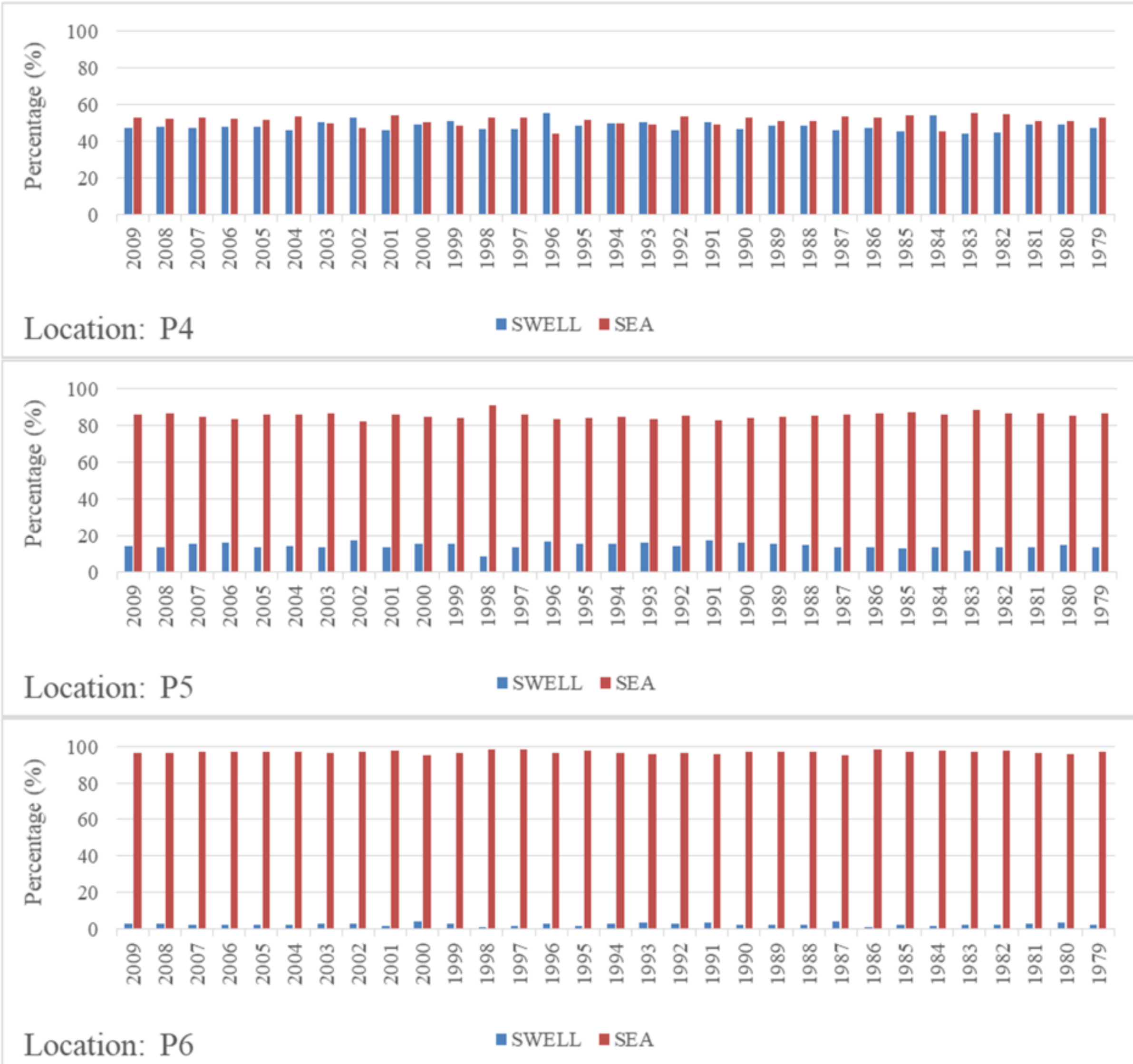

Figure 5. The percentage (%) of dominance of swells and seas at P4 – P6 for the different years of the study period

Conclusions

Contribution of swells to wave climate was investigated at six locations off the south western coasts of the Black Sea for the period from 1979 to 2009. The dominant wave pattern in the study area was studied by classifying the wind sea and swell based on the wave steepness. The percentage of dominance of swells and seas for the different months and years of the study period was examined at locations considered. The results show that wind sea dominates along south western coasts, especially off Istanbul. The percentage of swells is comparable to the wind sea at other stations except for the location P1 which is located off Sinop. However, the interaction between the swells and wind seas must be better explored further to get a better understanding for example using spectral partitioning.

Acknowledgement

We express our great gratitude to The Turkish National Science and Technology Foundation (TUBITAK) which funded the research under the grant number 214M436.

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