Storm identification and assessment of potential impacts in Rhodes Island, Greece

Gad F.-K.[1,*], Chatzinaki M.[1], Vandarakis D.[1], Kyriakidou Ch.[1], Hatiris G.A.[1,2], Kapsimalis V.[1]

[1]Hellenic Centre for Marine Research (HCMR), Institute of Oceanography, 46.7 km Athens - Sounio Ave., P.O. Box 712, P.C.19013, Anavissos, Greece
[2]Harokopio University, Geography Department, El. Venizelou 70, 17671 Athens, Greece

*corresponding author : e-mail: fgad@hcmr.gr

Abstract
Coastal areas are threatened by extreme meteorological phenomena, such as wave storms. The analysis of wave storms is a key element in coastal management, as providing information for the assessment of their potential hazards on shores. In this study, a classification of storm events in Rhodes Island, Greece, is presented by means of cluster analysis. Storms were defined in terms of significant wave height, peak period and duration which are the main parameters reflecting their intensity, and they were classified into five groups, namely I-weak, II-moderate, III-significant, IV-severe, V-extreme. An assessment of storm impacts on shores was also carried out in terms of flooding and wave run-up was estimated by applying an 1-DH numerical model (MIKE21 BW).
Keywords: wave storms classification, coastal hazards, run-up, coastal flooding, Aegean Sea

1. Introduction

The analysis of wave storms and the assessment of their potential impacts on shores are essential for mitigating hazards and protecting coastal areas. Several studies have focused on coastal floods (Mendoza *et al.*, 2011, 2013), one of the most common hazards caused by wave storms. This study presents the analysis of storms in Rhodes Island, Greece and the assessment of coastal inundation by applying an 1DH numerical model (MIKE 21 BW) for wave run-up calculation. The study area is located in north and northwest coast of the island extending from its northern tip (Cape Mylon) to Fanes (about 26 km length) (Figure 1). This area is of great importance due to high population density and significant economic activities, such as tourism. The wave data used for the analysis were derived from the "Wind and Wave Atlas of the Hellenic Seas" (Soukissian *et al.*, 2007), covering a 10-year period (1995-2004).

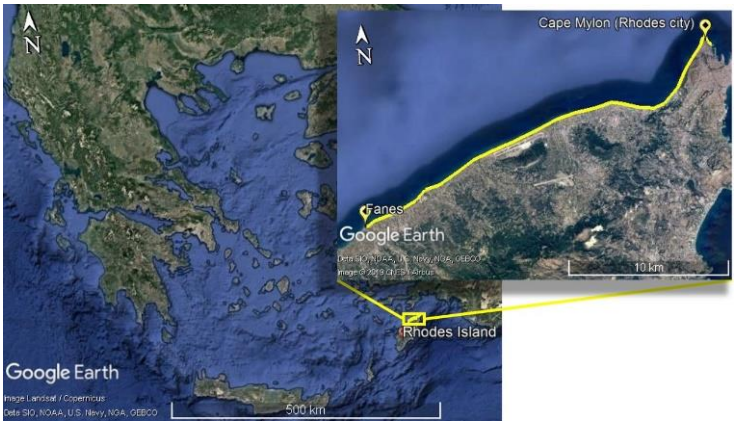

Figure 1. The case study area, Rhodes Island, Greece.

2. Methodology

The assessment of potential flooding hazard due to storm events comprises storm definition and classification, as well as wave run-up estimation. In this study, a wave storm is defined as an event in which significant wave height (Hs) exceeds the 95th percentile of the data set (Martzikos *et al.*, 2018) with a minimum duration of 6 hours (Mendoza *et al.*, 2011). Also, when the calm period between two consecutive storms is shorter than 24 hours these events are considered as one with two peaks (Rangel-Buitrago and Anfuso, 2011). Concerning storm direction, only events propagating towards the shore were included in the analysis. After identifying storms, they were classified through cluster analysis by using the variables of energy content and peak period, which reflect storm intensity. The wave

energy content has been expressed by Dolan and Davis (1992) as:

$$E = \int_{t1}^{t2} H_s^2 dt$$

where H_s is the significant wave height and $dt=t_2-t_1$ is the storm duration. The average linkage method was used for storm classification into five groups, namely I-weak, II-moderate, III-significant, IV-severe, V-extreme as proposed by Dolan and Davis (1992). Finally, the inundation hazard was assessed by calculating the wave run-up on representative cross-shore profiles by MIKE 21 BW (1DH) model.

3. Results

The most intense storms occur in the eastern part of the study area, where the greatest values of Hs have been recorded (Table 1). However, most storms occur in the western part. More than half of the events were classified as weak (Class I), while extreme storms (Class V) occur with a frequency of 1% and 2% in east and west area, respectively. Wave storms propagate mostly from SE and W in east and west area, respectively. As concerns coastal flood potential, the maximum value of wave run-up ranges from 0.33 m to 1.33 m for extreme events at the selected profiles, while its mean value ranges from 0.13 m to 0.54 m.

4. Conclusion

According to storm analysis the most intense events occur at the eastern part of the study area, due to strong southeast waves, however this region is not threatened by flooding hazard. On the other hand, the model results reveal that the central-west part of the study area (eg. Kremasti) with mild slopes, exposed to less intense storms propagating from west sector, presents a threat to flood during extreme storms, as wave run-up may exceed beach berm elevation during an event.

Table 1. Averaged storm characteristics for each class.

Class	Hs (m)	Tp (s)	Direction (degN)	Duration (h)	Energy (m^2h) [range]	No of events	Frequency
Eastern part							
I	1.8	6.9	149	21	78.2 [12.6-178.6]	75	75%
II	2.2	7.7	163	57	273.2 [206.7-325.1]	18	18%
III	2.1	7.8	155	79	373.2 [339.8-431.7]	3	3%
IV	2.5	8.4	175	73	530.8 [511-549.7]	3	3%
V	2.9	8.8	154	69	681.2	1	1%
Western part							
I	1.4	7.3	271	13	28.4 [9.5-58.7]	75	60%
II	1.6	8.0	268	39	97.1 [63.2-148.5]	44	35%
III	1.8	8.9	251	59	193.3 [166.6-207.4]	6	5%
IV	1.8	10.2	257	66	227	1	1%
V	2.0	9.3	250	65	281.4 [264.3-299.6]	3	2%

Acknowledgments

This research was funded by GLAFKI – "Blue growth with innovation and application to the Greek Seas" program [MIS 5002438] (funded by the National Strategic Reference Framework).

References

Dolan R. and Davis R. E. (1992), An intensity scale for Atlantic coast northeast storms, *Journal of Coastal Research*, 840–853.

Martzikos N., Afentoulis V. and Tsoukala V. (2018), Storm clustering and classification for the port of Rethymno in Greece, *Water Utility Journal*, **20**, 67-79.

Mendoza E. T., Jimenez J. A. and Mateo J. (2011), A coastal storms intensity scale for the Catalan sea (NW Mediterranean), *Natural Hazards & Earth System Sciences*. Citeseer, **11**, 2453-2462.

Mendoza E. T., Trejo-Rangel M. A., Salles P., Appendini C. M., Lopez-Gonzalez J. and Torres-Freyermuth A. (2013), Storm characterization and coastal hazards in the Yucatan Peninsula, *Journal of Coastal Research*. Coastal Education and Research Foundation, **65**, 790–795.

Rangel-Buitrago N. and Anfuso G. (2011), An application of Dolan and Davis (1992) classification to coastal storms in SW Spanish littoral, *Journal of Coastal Research*, **64**,1891–1895.

Soukissian T., Hatzinaki M., Korres G., Papadopoulos A., Kallos G. and Anadranistakis E. (2007), Wind and wave atlas of the Hellenic Seas, Hellenic Centre for Marine Research, Anavyssos.