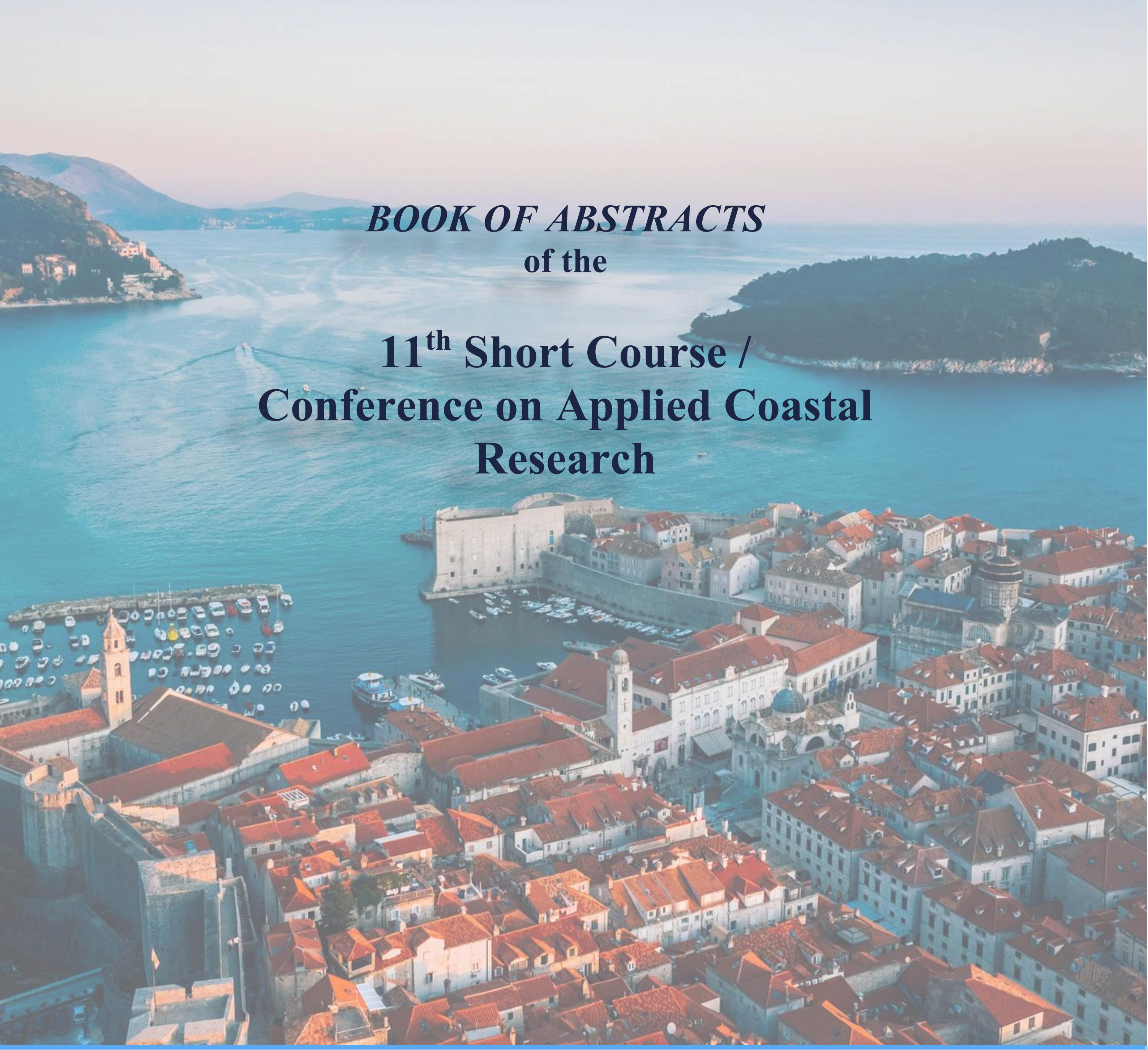

BOOK OF ABSTRACTS

of the

11th Short Course / Conference on Applied Coastal Research

September 24 – 26, 2025

Dubrovnik / Croatia

UNIVERSITY OF ZAGREB FACULTY OF CIVIL ENGINEERING

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Preface

It is with great pleasure that we present the Book of Abstracts for the *11th Short Course / Conference on Applied Coastal Research (SCACR 2025)*, held in the beautiful city of Dubrovnik, Croatia, from 24 to 26 September 2025. This year's organizing committee includes members from the University of Zagreb and the University of Dubrovnik, together with their partner institutions. This gathering brings together scientists, engineers, practitioners, students, and stakeholders from around the world who share a common interest in understanding, managing, and protecting coastal systems.

Over the past decades, coastal regions have become focal points of both opportunity and challenge. Rising sea levels, changing storm regimes, human development pressures, and ecosystem degradation place mounting demands on the disciplines of coastal science and engineering. In response, the coastal research community continues to evolve, innovating in methods, materials, modelling tools, and management strategies. The SCACR series of short courses and conferences has, since its inception, served as a platform for exchanging knowledge and promoting interdisciplinary dialogue.

The SCACR (Short Course / Conference on Applied Coastal Research) community is a vibrant and inclusive network bringing together students, experimentalists in the field and laboratory, theoreticians, and modelers whose work lies at the intersection of coastal science, engineering, and environmental management. It serves as a forum not only for presenting latest advances in research, but also for mentoring, capacity-building, and fostering interdisciplinary collaboration. By connecting early-career researchers with established experts, and by bridging theoretical, computational, and empirical approaches, SCACR aims to stimulate innovative solutions to pressing coastal challenges worldwide.

This year's meeting features a rich programme that spans fundamental research, modelling, field investigations, laboratory work, and applied case studies. The conference program is further enriched by six keynote lectures delivered by distinguished experts who will share their insights on emerging challenges in coastal research Abstracts included in this volume cover a wide range of topics such as coastal morphodynamics, sediment transport, coastal protection and port structures, resilient coastlines, climate change impacts, coastal hazards, monitoring and remote sensing, ecosystem-based adaptation, and sustainable management practices. The short course held in conjunction with the main conference provide invaluable opportunities for early-career researchers to build capacity and learn state-of-the-art techniques with experts in small-group, hands-on settings.

We are delighted by the strong and diverse response to our call for abstracts, with more than 60 contributions selected for presentation in either oral or poster format. Among these, 20 full-length papers that cover a broad range of the conference's scientific themes is being published in Special Issue of the open-access journal *Coastal and Offshore Science and Engineering*. The submitted works represent 17 countries, reflecting both global and regional perspectives, and highlighting the increasing relevance of coastal issues in Europe and beyond. We believe this cross-fertilization of ideas between different geographies, disciplines, and methodological approaches is essential to advancing solutions that are both scientifically robust and societally meaningful.

The success of SCACR 2025 owes much to the dedication of many. We wish to express our deep gratitude to the invited speakers, advisory and scientific boards, session chairmans, and reviewers for their careful evaluation of abstracts and full papers. Special thanks go to our sponsors and supporting organizations, whose generosity helps make this conference possible and ensures that its impact extends broadly across the research, policy, and practitioner communities. We also acknowledge the efforts of the University of Dubrovnik for providing logistical support, facilities, and coordination.

As you browse through this Book of Abstracts, we hope you will find not only the scientific rigor and technical detail that you expect, but also inspiration, new ideas, and potential new collaborations. May the presentations, discussion and informal exchanges in Dubrovnik spark insights that drive forward the science and practice of applied coastal research.

Dalibor Carević and Marijana Pećarević

Content

1. COASTAL MORPHODYNAMICS, PLASTIC TRANSPORT & SHORELINE CHANGE

ESTIMATION OF RIPPLE CHARACTERISTICS AND BEDLOAD FLUXES FROM SONAR DATA AND NUMERICAL MODELING

M. SAID PARLAK [1], B. UMUT AYHAN [1], TARANDEEP S. KALRA [2], ILGAR SAFAK [1]

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Abstract

Hydrodynamic and morphodynamic processes are critical for coastal and nearshore applications. Therefore, numerical models are developed for accurate forecast of these processes. Validation of these models is quintessential and requires field observations of high spatial and temporal resolutions. Sediment processes and field conditions bring uncertainties and challenges on direct measurements of bed ripple characteristics and bedload fluxes. Sound Navigation And Ranging (SONAR) scans of sea bed is a common method to estimate bedload fluxes. The SONAR scans of sea bed over the sand deposits off Fire Island, New York were collected at 12 m depth during a field experiment. The signals of scans were first filtered to eliminate noise, then, a Fast-Fourier-Transform (FFT) analysis was applied to evaluate the ripple characteristics (Figure 1a, b, c).

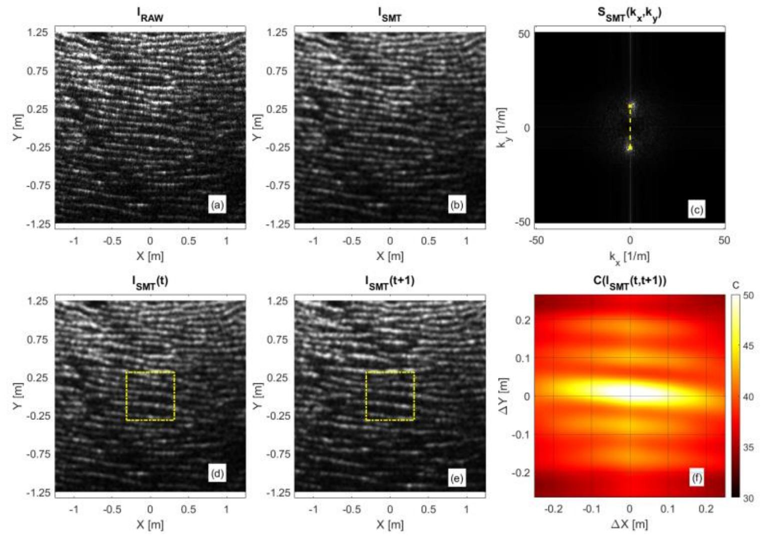

Figure 1. (a) Unfiltered, I_{RAW}, and (b) filtered, I_{SMT}, SONAR scans from the same instance; (c) FFT result; (d, e) filtered consecutive scans; and (f) cross-correlation, *C*, of the area indicated by yellow lines.

The migration rates of the ripples were determined by applying two-dimensional cross-correlation to consecutive images (Figure 1d, e, f). The total volume of bedload transport was estimated by combining the migration rates and the ripple characteristics. A hydrodynamics-processed based numerical model was set up and applied at the study site in order to assess decadal scale morphodynamics. Bedload flux results of the model were found to qualitatively agree with the observations based on the SONAR scans.

Keywords: bedload transport, cross-correlation, ripple migration, morphodynamics, SONAR data processing

PROBABILISTIC TSUNAMI HAZARD ASSESSMENT OF SUBMARINE LANDSLIDES IN THE MARMARA SEA

TOMOYA KURIHARA[1], CEREN ÖZER SÖZDİNLER[2], AHMET CEVDET YALCINER[3], TOSHITAKA BABA[4], TARO ARIKAWA[1]

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Abstract

1) Background: The Sea of Marmara, where the North Anatolian Fault (NAF) consists of numerous fault segments extending along the Northern Aegean Sea, has experienced many earthquakes and associated tsunamis in the past and present. One notable event was the 1509 Constantinople earthquake with an estimated magnitude of 7.2 ± 0.3 which generated a tsunami over 6 meters high along the Istanbul coasts and caused significant damage and many loss of lives. Due to its lateral strike-slip fault characteristics, NAF is considered unlikely to generate large tsunamis from earthquake rupture. Therefore, this study investigates the possibility of submarine landslides induced by seismic activity. Considering the uncertainty of submarine landslide parameters, we estimate the tsunami recurrence interval using a probabilistic approach, assuming that the 1509 tsunami was caused by a submarine landslide.
2) Method: Submarine landslides involve uncertainties such as the shape and onset time of sliding. Therefore, a probabilistic approach is required for numerical calculations. The study defined eight submarine landslide bodies based on geological and geomorphological studies in the Sea of Marmara and created submarine landslide models using the Monte Carlo simulation method (Nagai et al., 2022). From these, 100 scenarios were generated to calculate tsunami propagation. An empirical distribution function was derived from the maximum tsunami heights along the Istanbul coast, and the smoothing method of Fukutani et al. (2021) was applied. Finally, the tsunami hazard curves were calculated by multiplying the inverse of the mean recurrence interval of the earthquake magnitude.
3) Result: Fig. 1a shows the empirical distribution function based on the worst-case scenario, and Fig. 1b shows the hazard curve calculated from Fig. 1a. The analysis results indicate that, considering the worst-case scenario and the 1509 earthquake magnitude, the 6-meter tsunami in 1509 corresponds to a recurrence interval of approximately 700 to 3000 years.

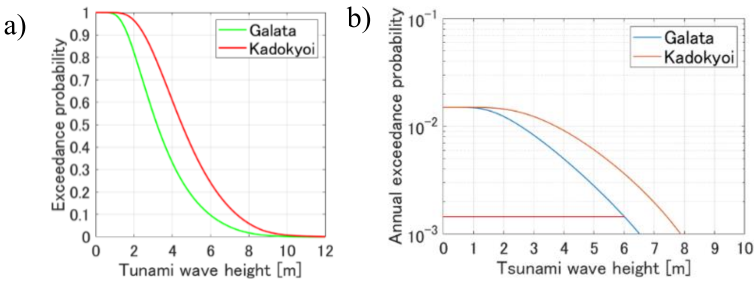

Figure 1. a) Empirical distribution function obtained from the results of 100 scenario calculations. b) Tsunami hazard curve derived from the empirical distribution function.

Keywords: submarine landslide tsunami, Marmara, probabilistic assessment, two-layer model

IMPACT OF SURFACE WAVE ASYMMETRY ON THE TRANSPORT DIRECTION OF PLASTIC PELLETS WITH DIFFERENT DENSITIES

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Abstract

When waves approach the shore, a transformation occurs in the wave train from sinusoidal waves to waves with greater asymmetry. The shape of the wave begins to change, giving rise to waves with peaky and sharp crests and longer, flatter troughs (velocity-skewed waves). The effect of asymmetry is visible on the free surface, but this asymmetry extends into the water column, directly influencing the seabed and elements moving across it (sediments, debris). As the L/h ratio increases, waves take on a forward-leaning shape with a steep frontal face and a gentle trough. These are waves characterized by acceleration skewness, and the mechanism for the transformation of wave shape primarily results from the nonlinear interaction of waves that amplify higher harmonics. The diversity of surface wave characteristics interacting with bottom ripples generates variations in sediment transport patterns.

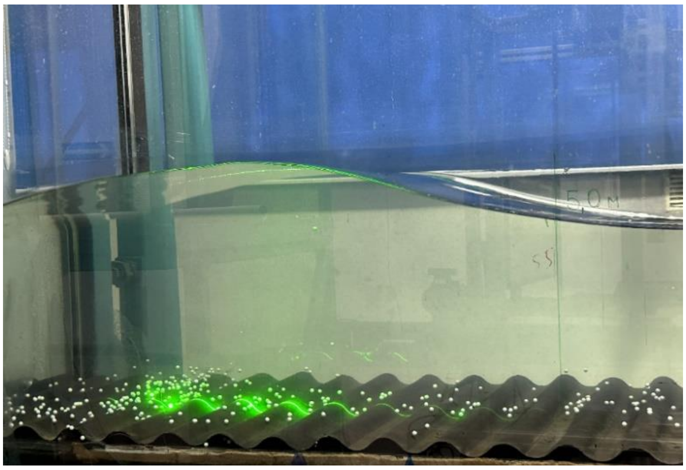

Figure 1. Plastic pellet traveling along the rippled bottom during PIV experiments in the wave flume.

As indicated by the literature, under the influence of waves characterized by velocity skewness, sand is transported in the direction opposite to the wave approach (offshore), whereas with waves characterized by acceleration skewness, sand is consistently transported onshore. However, laboratory studies presented by the author suggest that for plastic pellets with a density lower than quartz and dimensions larger than sand grains, the transport pattern may differ significantly. The impact of various surface wave parameters on the transport direction of plastics with varying densities was investigated. Factors influencing the change in transport direction of plastic debris moving along a ripple-covered bottom under the influence of nonlinear surface waves were also examined. Marker studies and PIV measurements were conducted to determine the velocity and direction of plastic movement for pellets of different densities. The experiments indicate that, in addition to the shape of the surface wave and seabed ripples, the density of plastic pellets significantly influences their transport direction along the sea bottom.

Keywords: velocity skewness, acceleration skewness, plastic debris, negative buoyancy

VULNERABILITY ASSESSMENT OF STORM-INDUCED SHORELINE CHANGE THROUGH THE INTEGRATION OF EARTH OBSERVATION DATA

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Abstract

Intertidal zones are among the most dynamic coastal environments, characterized by variability driven by the interaction of wind and marine currents. The integration of recent advances in remote sensing and machine learning enables to investigate the impact of shoreline evolution induced by extreme events. Multi-decadal time series of imagery, acquired at intervals of a few days by high-definition multispectral satellite sensors, facilitate this analysis. Open-source software and Python tools further support the extraction of Satellite-Derived Shoreline (SDS) from Earth Observation datasets. The incorporation of historical tidal data, corrected taking into account the beach slope derived from unmanned aerial vehicle (UAV) surveys, allowed us to refine nominal shoreline positions within the analysed time series. This approach yielded a multi-decadal time series of shoreline positions, enabling the analysis of seasonal and long-term trends. Understanding the specific impacts of single extreme events on sandy beach dynamics using the above multidecadal record can be challenging. Here, we propose an integrated analysis which includes met-ocean information, i.e. extreme storm events gathered from CMEMS reanalysis wave datasets, to identify the influence of individual storms on shoreline change. The methodology compares the event characteristics (e.g. Hs, Tp, theta, energy, Storm Power Index, etc.) to the average shoreline movement induced by each specific storm. The results obtained from this analysis are used to understand the behaviour of the beach system in terms of erosion or accretion patterns induced by extreme events. Subsequent analysis of this phenomenon across various adjacent beaches permits the investigation of the contribution to resilience by anthropogenic or natural components.

In the case study, an analysis was conducted on the response beach behaviour to extreme events, during the 2018-2024, period on South-Est of Sicily. The SDS extraction procedure, employing machine learning algorithms on satellite images, has been validated using topographic data and UAV surveys. The validation considering the effects of seasonal conditions. A POT analysis is used to determine wave conditions during extreme storms. By overlaying the time series of Significant Height and SDS positions along transects, the position of the shoreline before and after every event can be determined. The integration of comprehensive event data facilitated the aggregation and categorization of the beach's behavioural patterns. A comparative analysis of beaches with varying composition of natural and anthropogenic elements enables the investigation of the contribution of resilience provided by barriers or seagrass in a beach system. The outcomes of this study can be applied to various analyses, including the assessment of performance levels in terms of response to storms, the monitoring of the health of the beach system, and the prediction of behaviours in the context of climate change scenarios.

Keywords: coastal erosion, beach morphodinamics, Satellite Derived Shoreline, seagrass

STORM-INDUCED MORPHODYNAMICS ON CROATIAN ARTIFICIAL POCKET BEACH

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Abstract

Artificial gravel beaches play an important role in coastal protection and the development of tourist infrastructure, especially in coastal regions with limited natural recreational resources, such as the Croatian Adriatic coast. Due to increasing wave action and anthropogenic impacts, the stability of these beaches is often at risk and effective engineering solutions are needed to reduce sediment loss and ensure long-term functionality. Coastal structures such as submerged sills are increasingly being used to reduce wave energy and limit sediment transport. While their effectiveness on sandy beaches is relatively well researched, their effects on gravel beaches, especially in fetch limited coastal areas, are still poorly understood.

The aim of this study is to analyze the influence of sill crest depth and beach slope on the morphodynamics of artificial gravel beaches through a combination of systematic field observations and numerical modeling. Numerical simulations were performed using the process-based model XBeach-Gravel, which was specifically developed for gravel beaches with dominant cross-shore sediment transport. The XBeach-Gravel model was calibrated and validated using field data collected from the Ploče artificial gravel pocket beach in Rijeka. The calibration of the model focused on optimizing three key parameters for sediment transport to improve accuracy under Adriatic wave conditions. After calibration on the western cell, the model was validated on the eastern cell with a different orientation, which served as an additional check of the selected sediment transport parameter set. The validation confirmed the model's ability to reliably reproduce the observed profile changes and the model was used to simulate a series of idealized storm scenarios that allowed a sensitivity analysis and an assessment of the protective function of the submerged sill under different wave conditions. A total of 144 configurations were analyzed, combining three sill crest depths (without sill, 1 m, 2 m and 3 m below mean sea level) with four beach slopes (6°, 7°, 8° and 9°) and 9 tests of storm scenarios with characteristic wave conditions representative of storm events in the eastern Adriatic. The results have shown that the presence and geometry of the submerged sill have a significant impact on key morphodynamic indicators, including berm formation, wave run-up and sediment displacement. The most favorable configuration was achieved with a sill crest depth of 3 m and a beach slope of 6°, resulting in minimal erosion on the lower beach profile, reduced sediment transport to the upper part of the profile, and consequently a lower berm elevation.This study confirms that optimizing the geometric design of submerged sills, especially the crest depth depending on the local bathymetry and beach slope, is crucial for improving the resilience of artificial gravel beaches. The results provide valuable guidance for coastal engineers and planners as they show how subtle changes in profile geometry can influence beach response during storms. The chosen approach, a combination of site-specific calibration of numerical model and systematic parametric testing can be applied to similar microtidal and fetch-limited coastal environments. Ultimately, this research supports the development of robust, sustainable and low-maintenance gravel beaches that are able to withstand increasing storm frequency under future climate scenarios while maintaining their recreational and protective functions.

Keywords: pocket beaches; sediment transport; Xbeach-G; submerged sill; gravel

OVERALL SHORELINE CHANGE ANALYSIS ALONG THE COAST OF GHANA FOR AN INTEGRATED SEDIMENT MANAGEMENT

DAIKI TSUJIO [1], YOSHIMITSU TAJIMA [2], LIANHUI WU [3], DONATUS ANGNUURENG [4]

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Abstract

In the West African region, coastal erosion, coastal flooding, and pollution are becoming evident, and with the impact of climate change, further deterioration is concerned for the future. In this region, the longshore sediment transport goes across countries, and it is necessary to manage coastline and sediment budget from the perspective of the entire West African region, beyond focusing on single region or country. This study aims to overlook the shoreline change along the coast of Ghana for the ultimate goal of establishing an integrated sediment management method in West Africa.

While this study targeted the whole coast of Ghana, here we presented the studies conducted for the Volta River Estuary (Keta area, Fig. 1(a)), Densu Delta, and Anlo Beach. This paper utilized CoastSat to understand the shoreline changes using satellite images and conducted field inspections to analyze the factors contributing to coastal dynamics at each coast.

For example, the analysis results by CoastSat showed that erosion and accumulation occurred at east and west side of the groins constructed in 2016, respectively (see Fig.1 (d) and (e)), indicating the dominance of the eastward longshore sediment transport. It is clearly consistent with the actual situation (see Fig.1 (b) and (c)). Fig. 1 (a) also describes overall characteristics of the shoreline changes and longshore sediment transport deduced from the observed shoreline and wave conditions along the coast of the Volta River mouth. Construction of Akosombo Dam appears to significantly reduce the sediment supply to the coast, resulting in the overall erosion trend while construction of groins and seawall show some function to mitigate the erosion. For countermeasures, therefore, it is necessary to fully understand the sediment budget from the perspective of a large area by observation and measurement of fundamental information: the estuary form change, inflow and deposition of sediment, nearshore waves, and bathymetry.

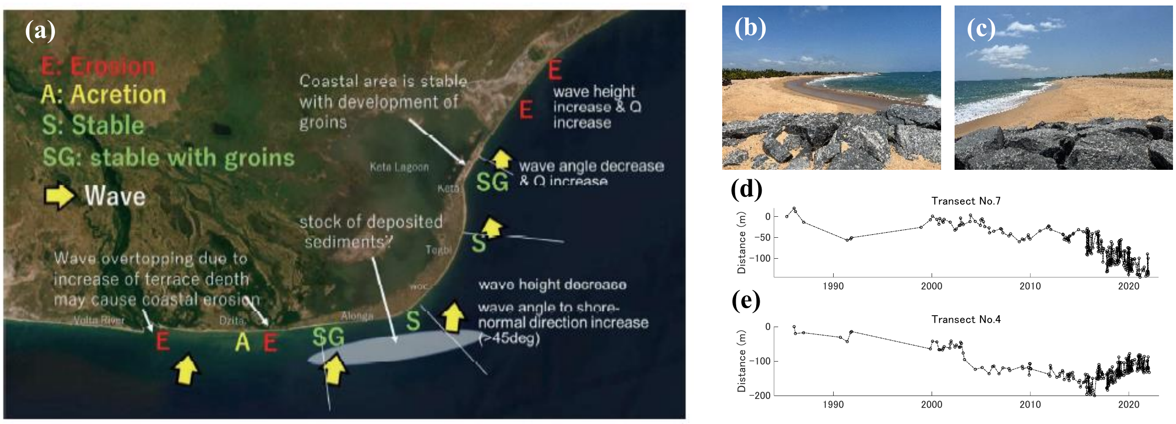

Figure 1. (a) Sediment transport characteristics around the Volta River, **(b)** east and **(c)** west side of the groins in the Keta area and shoreline change at **(d)** east and **(e)** west side of the groins in the Keta area.

Keywords: longshore sediment transport, satellite image analysis, cross-border sediment

2. COASTAL STRUCTURES, PORTS, HARBOURS AND WATERWAYS

SPECTRALWAVES.JL: JULIA PACKAGE FOR MODELLING OF NONLINEAR WAVES PROPAGATING OVER TOPOGRAPHY

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Abstract

We present a Julia implementation of a Fourier Galerkin method applied to nonlinear water waves propagating over an uneven bottom surface within a framework of a potential flow theory. The wave problem is formulated in a periodic domain of length l and still water depth d with a coordinate system located at an undisturbed free surface. Functions $\eta(x, t)$ and $\beta(x, t)$ define positions of water and bottom surfaces, respectively, while a velocity vector field is expressed by means of a velocity potential $\Phi(x, z, t)$. The initial boundary-value problem is displayed in Table 1.

Table 1. Initial boundary-value problem of waves propagating over topography.

EQUATION	REGION	DESCRIPTION
$\phi_{xx} + \phi_{zz} = 0$	$-d + \beta \le z \le \eta$	Laplace equation
$\eta_t + \eta_x \phi_x - \phi_z = 0$	$z = \eta$	Kinematic free-surface boundary condition
$\phi_t + \frac{{\phi_x}^2}{2} + \frac{{\phi_z}^2}{2} + g\eta = 0$	$z = \eta$	Dynamic free-surface boundary condition
$\beta_t + \beta_x \phi_x - \phi_z = 0$	$z = \beta - d$	Kinematic bottom-surface boundary condition

The solution is derived in terms of amplitudes of free-surface elevation and velocity potential, while inverse Fourier transform is used to get a phase-resolved wave field. Four wave generation mechanisms are supported - initial conditions, wavemaker forcing, pressure forcing, and a moving bottom. For simplicity, all parameters and solution coefficients are enclosed in a struct `Problem`, which may be modified and read from by external functions to conduct all modeling stages in an easy and efficient way. The package repository page is http://github.com/mcpaprota/SpectralWaves.jl where some basic applications of the model are reported, including e.g. shoaling waves presented in Figure 1 below.

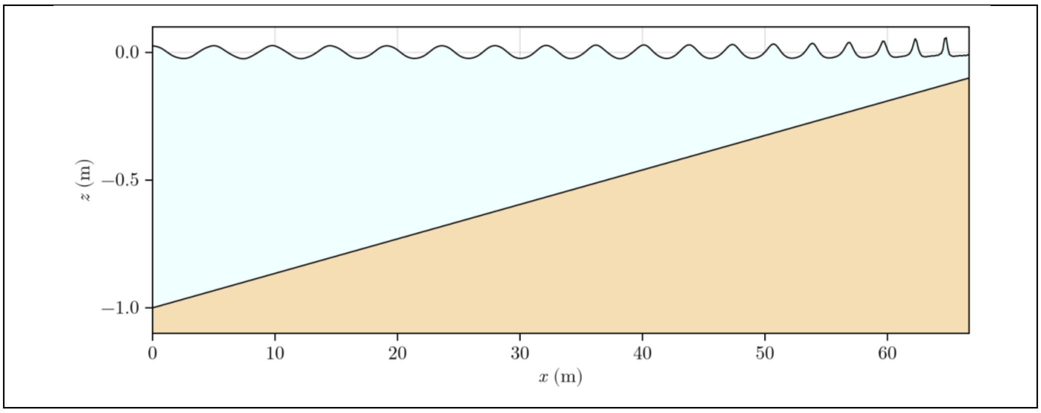

Figure 1. An example of model application to shoaling waves.

Keywords: water waves, uneven bottom, moving bottom, numerical model, potential flow

INFLUENCE OF SPECTRAL CUTOFF FREQUENCY ON ARMOR STABILITY IN SHALLOW WATER

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Abstract

Assessment of incident wave conditions at the toe of a rubble mound breakwater is a critical aspect for its design. In shallow water, spectral transformations due to depth limitations significantly alter wave-structure interaction processes such as wave overtopping and armor stability. Traditional design equations rely on spectral parameters, including the significant wave height (H_{m0}) and spectral wave period ($T_{m-1,0}$), computed over the entire frequency spectrum. However, in very shallow and extremely shallow water, the spectral shape is substantially modified, with reduction of swell energy due to breaking and frictional dissipation and increasing energy in upper and lower harmonics. Generation of infragravity (IG) energy dramatically shifts the bulk wave period lower and affects wave interaction with structures. The present study examines the sensitivity of armour stability prediction to different spectral cutoff frequencies used to separate long and short waves, assessing whether filtering out IG waves improves stability estimations or whether the wave steepness in stability expressions should be based on the entire wave spectrum or on the short waves only. A new stability expression including the wave steepness based on filtered spectral parameters ($H_{m0,F}$ and $T_{m-1,0,F}$) is introduced, with the corresponding short-wave steepness ($s_{m-1,0,F}$) proposed to better characterize the destabilizing forces of short waves. A comprehensive analysis of 33 experimental tests from Scaravaglione et al. (2024) is conducted to evaluate the effects of various cutoff frequencies, expressed as multiples of the offshore spectral peak frequency (f_p), across a range of water depth conditions from deep to extremely shallow water. Filtering the spectrum to obtain a wave steepness based on short waves only reduces outliers and confirms that the total wave energy expressed by H_{m0} is an insufficient proxy for destabilizing energy in shallow water. The optimal cutoff frequency is identified by minimizing stability prediction errors while ensuring consistency with wave transformation processes. Adopting a filtered spectral approach improves stability assessments, yielding more reliable design parameters for coastal structures across all water depth regimes.
This study highlights the need to appropriately assess a characteristic wave steepness to accurately account for the influence of the wave steepness, especially for conditions in shallow water, with the aim of enhancing the predictive capabilities of armor stability.

Keywords: rubble mound breakwater stability, shallow water, infragravity waves, spectral wave filtering, wave steepness

OPTIMIZATION UNDER UNCERTAINTY OF WAVE OVERTOPPING FOR RUBLLE-MOUND BREAKWATERS

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Abstract

Reliable design for rubble-mound breakwaters to limit excessive overtopping in fetch-limited settings requires accounting for multi-source uncertainty—environmental variability, empirical model error, and construction tolerances—rather than relying on specific design wave height and sea level. This study demonstrates an optimization-under-uncertainty (OUU) framework for overtopping, applied to a planned breakwater at a steep sea bottom of 1:5 near Rijeka (Croatia). The objective of this study is to minimize the cross-sectional area of the rubble profile, A, subject to overtopping-based serviceability and ultimate limit state constraints and practical geometric bounds.

Overtopping discharge q is evaluated with the recent formulation of Etemad-Shahidi, Koosheh & van Gent (2022). Uncerainty in input parameters are assumed to be normally distributed, with the friction modifier γ_f modeled with a $\sigma(\gamma_f) = 0.05$, crest freeboard $\sigma(R_c) = 0.06$ m and seaward slope $\sigma(\tan \alpha) = 0.01$, while overtopping model uncertainty is taken into account by using coefficient uncertainty as reported in the original paper. Design variables that are part of the optimization cycle are R_c, $\tan \alpha$, and crest width G_c, and are bounded by 1 m $\leq R_c \leq$ 6 m, 0.40 $\leq \tan \alpha \leq$ 0.60, and 2 m $\leq G_c \leq$ 6 m. The optimization is constrained by $q^{\mathrm{AEP}=10\%} < 5$ l/s/m for serviceability and $q^{\mathrm{AEP}=2\%} < 20$ l/s/m for structure resilience. Considering the parameter uncertainty and 70-year sequences of significant wave height, H_{m0}, and sea level SL, overtopping time series are produced for each geometrical iteration of the rubble-mound breakwater geometry. Overtopping rates at AEPs of interest are extracted via Peaks-Over-Threshold (POT) method with a target average of 2-3 storms per year, while using reliability indices $\beta \in \{1, 1.5, 2\}$ for resulting AEP uncertainty. The uncertainty quantification employs Latin Hypercube Sampling (LHS) with a sampling budget of 100, while the OUU loop is solved with Efficient Global Optimization (EGO).

The optimized geometry consistently favors higher crests and steeper seaward slopes, which is expected due to the steep bottom seabed. The SLS target $q^{\mathrm{AEP}=10\%}$ is the primary limiting factor as the wave storms are constrained by the fetch and thus the difference between 10-year and 50-year significant wave height is not substantial but have notable difference in limiting values. Sensitivity experiments indicate that increasing the LHS number of samples from 100 to 200 does not shift the optimum geometry, thus showing the robustness of the method. By increasing the reliability index (β) we increase the safety margin by rising the optimal R_c from 4.5 m to 4.8 m. On the other hand, the joint probability return period approach for wave height and sea level gives lower overtopping values by a factor of 1.3 for β=1 and factor of 1.8 for β=2 when compared to the probabilistic approach in this study. The results demonstrate that reliability-consistent OUU provides materially different and more robust designs than deterministic pairings, especially where non-stationary sea level and short wave records complicate extreme characterization. Future extensions will (a) include overtopping volumes, velocity and depth and additional limit states (e.g., armor stability) in a multi-objective setting, and (b) propagate uncertainty from wave-model hindcasts/forecasts to the overtopping response.

Keywords: overtopping, rubble-mound breakwater, OUU, reliability, waves, sea level

HYDRAULIC BEHAVIOR OF TANDEM BREAKWATERS

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Abstract

Global climate change, particularly increased storm surges and rising sea levels, threatens coastal infrastructure, necessitating sustainable solutions. Breakwaters, essential yet costly structures, require innovative designs to balance economic and ecological considerations. A tandem breakwater system, incorporating a low-crested breakwater (LCB) in front of a conventional breakwater, offers a promising approach. However, research on this topic has only recently begun to emerge, with initial studies conducted by Van Gent (2024) and Thesnaar (2015). This study aims to enhance knowledge of fundamental design principles through physical model studies, providing valuable insights to both practicing engineers and researchers to address key challenges and develop effective coastal protection solutions.

This study focuses on determining the hydrodynamic conditions in front of a conventional main breakwater located behind the low-crested breakwater. The key parameters to be analyzed include: (i) Transmitted wave conditions, (ii) Wave setup, (iii) Flow kinematics and turbulence parameters using “Particle Image Velocimetry (PIV)” measurements due to interactions of both structures. Before positioning the structures in a tandem arrangement, the performance of the low-crested structure was analyzed in the absence of a conventional main breakwater, focusing on wave transmission, reflection and hydrodynamic structure around the LCB. The tested structures consisted of homogeneous rubble mound breakwaters with a trapezoidal shape, crest elevations of Rc = -0.30 m and -0.15 m, and slope angles of 1:2, and the effects of wave transmission and reflection were examined. The results were then compared with existing literature to assess the validity and relevance of the study. The wave steepness, calculated using the spectral wave period, ranged from $s_{m-1,0}$ = 0.02-0.04. The water depth in the wave flume was 0.60 m. Firstly, the transmission coefficient for a low-crested structure with two different crest elevations was analyzed and evaluated using the formula provided by Van Gent (2023). The comparison indicates an underestimation of the measured values, particularly for R_c = -0.15 m. The overall bias of K_t is 0.046 and 0.08 for R_c = -0.30 and -0.15 m, respectively. Testing for different crest elevations is still ongoing, and these findings represent only preliminary results of the experiments. Tandem breakwaters offer a sustainable and innovative approach to coastal protection. Since this is an ongoing study, detailed results will be provided in the next full-text submission.

COASTAL VULNERABILITY AND BEACH EROSION IN HAVIŠĆE BAY: IMPACTS OF URBANIZATION AND CLIMATE CHANGE

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Abstract

The research is being conducted as part of the Interreg - RESONANCE program, focusing on the Adriatic coast, which has experienced significant urbanization, driven by the rapid expansion of the tourism industry. However, this development, combined with the impacts of climate change, poses a growing threat to both infrastructure and local communities along the coast.

A prime example of such vulnerability is Havišće Bay, which serves as the main study area. This location falls within a zone classified as having moderate to very high coastal vulnerability, primarily due to its poor geotechnical properties [1]. Based on analysis of orthophotos, dating back to 1968, and preliminary simulations using the SWAN model, it was observed that these conditions have led to landslides and cliff erosion, which have contributed to beach nourishment. The majority of sediment nourishment came from the erosion of rocks on the eastern shore, with material being broken down and moved westwards alongshore by south-easterly waves as shown in Figure 1. Moreover, the central part of the bay, formed in flysch, is particularly prone to landslides and also contributes to the beach nourishment. However, due to inadequate coastal development, these natural processes have been disrupted, leading to a loss of the beach sediment, especially on the east part of the beach. As a result, approximately one-third of the beach area has been eroded since 1968.

Havišće Bay highlights the effects of rapid coastal development, where growing number of homes has disrupted the natural processes that once sustained the beach, leaving these areas increasingly vulnerable to extreme waves and rising sea levels.

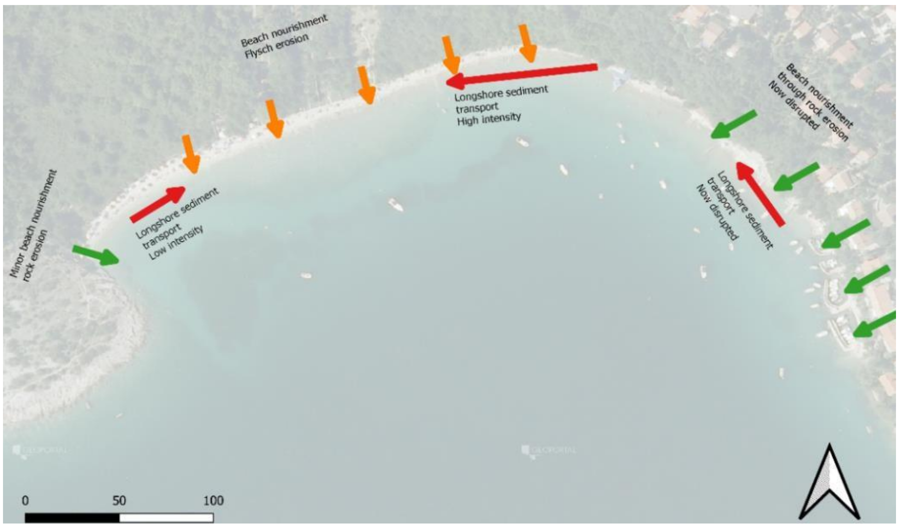

Figure 1. Beach nourishment model in Havišće Bay

Keywords: coastal development, sea level rise, landslide risk, sediment transport

SCOUR PHENOMENA NEAR A DETACHED LOW-CRESTED RUBBLE-MOUND BREAKWATER

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Abstract

Detached low-crested rubble-mound breakwaters (DLCRBs) are widely used in coastal protection all around the world, but their stability is threatened by scour phenomena induced by wave and current interactions. This study presents an integrated analysis of scour development around DLCRBs, combining physical and numerical modelling techniques. A 3D mobile bed physical model, built on a geometrical scale of 1:25, was used to investigate the evolution of scour holes near a DLCRB (1V:2H) (Figure 1). The experiments were performed in the Hydraulics Laboratory of the Faculty of Engineering of the University of Porto, Portugal. A total of 29 tests were carried out, covering a range of parameters: the number of waves (N) varied between 1000 and 11000, the freeboard (R_c/h) ranged from -0.13 to 0.23, the relative water depth (h/L_p) spanned from 0.05 to 0.08, and the significant wave height (H_s) was between 0.064 m and 0.129 m. Advanced monitoring techniques and post processing methodologies, including high-resolution laser scanning (FARO FOCUS s70) and wavelet analysis, enabled precise characterization of seabed morphodynamics. Complementary numerical modelling was performed using OpenFOAM with the IHFOAM solver to accurately simulate wave interaction with the porous structure. A novel methodology was implemented to identify potential scour development zones based on hydrodynamic results, providing a predictive tool for erosion risk assessment.

Results demonstrate the significant influence of wave reflection, freeboard conditions, and wave-structure interactions on scour depth. Furthermore, new key variables have been identified as crucial in determining scour hole development near the breakwater trunk such as: the reflection coefficient (K_r), the number of waves (N), the freeboard parameter (R_c), the significant wave height (H_s) and the water depth to wavelength ratio (h/L_p). These variables, which go beyond those typically considered in existing formulations, suggest potential for the development of a more effective predictive formula for scour.

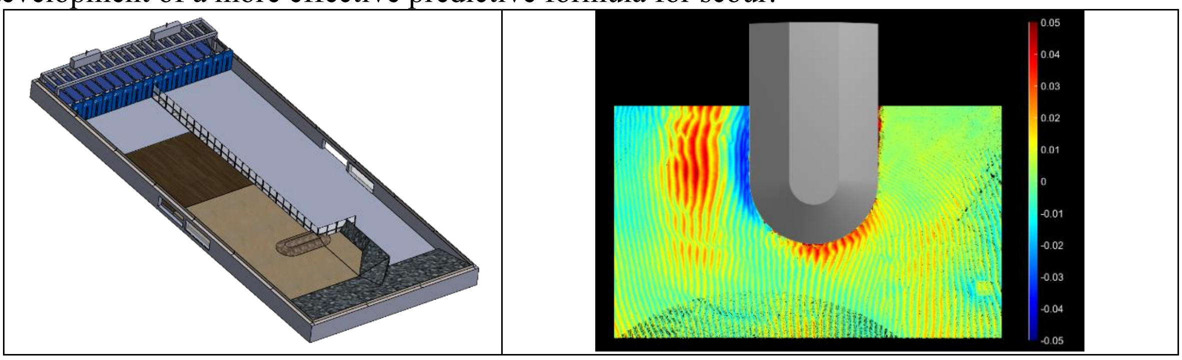

Figure 1. Physical experiments: 3D Layout (left) and final scan after 5000 waves (Hs = 0.077; h/Lp = 0.063, Rc/h = 0.23) (right).

Keywords: 3D mobile-bed physical model, bed shear stresses, CFD, IHFOAM, Wave-Structure-Seabed Interaction (WSSI)

NUMERICAL INVESTIGATION OF PORE PRESSURE DISTRIBUTION INSIDE A RUBBLE MOUND BREAKWATER

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Abstract

The analysis of pore pressure distribution within a rubble mound breakwater is a key aspect, as it significantly affects the structure stability and hydraulic performance. However, existing building methods often ignore the pressure field within the structure body. Moreover, the scarcity of experimental data on wave-induced pressures, particularly under depth-limited conditions, creates significant knowledge gaps that limit the optimization of breakwater design.

This study addresses these gaps by investigating the pore pressure distribution inside rubble mound breakwaters subjected to depth-limited water conditions. The methodology aims to generate a comprehensive dataset of internal pressures inside the breakwater. A numerical approach was adopted, utilizing Computational Fluid Dynamics (CFD) with OpenFOAM to simulate wave dynamics in a two-dimensional channel. This CFD toolbox was selected for its flexibility, open-source nature, and reliable capabilities in addressing complex fluid dynamics problems in coastal engineering, including the study of flows within porous media and the analysis of fluid-structure interaction. The numerical model calibration and validation, obtained using a complete set of calibration parameters listed in Tab. 1, were conducted using wave and pressure data from a recent experimental campaign conducted by Scaravaglione et al. (2024). These experimental results, obtained under shallow water conditions, were essential for establishing the accuracy of the numerical model across a wider range of wave boundary conditions and structure geometries.

Table 1. OpenFOAM calibration parameters

TIME STEP (s)	CELL SIZE (m)	COURANT NUMBER	TUNING FACTOR	FRICTION KS	TURBOLENCE MODEL	NUMBER OF WAVES	COMPUTATIONAL TIME (h)
0.025	0.03	0.65	1.6	40e-6 m	κ ω sst	500	15

Afterward, a new numerical simulation campaign is conducted to extend the dataset range, and an empirical formulation will be developed for predicting internal pressure across various foreshore configurations. By offering numerical tools, this work contributes significantly to the advancement of coastal defense design.

Keywords: Numerical modeling, OpenFOAM, Wave-structure interaction, CFD, shallow water.

COMBINED EXPERIMENTAL AND NUMERICAL APPROACHES TO ASSESS MOORING LINE TENSION AND FLOATING OBJECT DYNAMICS

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Abstract

Floating objects mooring is well known environmental problem offshore but also along the Mediterranean coast. For purpose of this paper, we consider floating objects of a laboratory scale, appropriate to perform 1:1 scale experiment. To determine the mooring line tension under different wind generated wave conditions offshore, two different approaches have been used, laboratory scale model performed within the laboratory facility and numerical simulation approach performed by Ansys Engineering Software.

Initially, 3D prints of the floating objects have been printed out with specific range of length, width and mass. Experiments are than implemented onto the lab scale with appropriate mooring setup. Spectral wind generated waves have been simulated to induce floating object degrees of freedom, heave, pitch and surge, respectively. Simultaneously, the mooring line tension is observed by the custom-made sensor installed onto the floating object.

Ansys diffraction and hydrodynamic modules have been used to perform grid and time step convergence tests and select appropriate model parameters. Model domain has been set up in correspondence to laboratory experiments with wave generated time series identical to those used within the lab experiment. Model parameters have been determined either from the material properties by the calibration process.

Once the model is calibrated, relevant simulations with appropriate parameter combinations have been conducted. From the obtained degrees of freedom and mooring line tension time series, following conclusions have been obtained. In the origin, floating object degrees of freedom are dominant factors defining the tension force. Furthermore, mooring concept leads towards the domination of separate degree of freedom to the mooring line forces. Typical mooring line tension induced by spectral wind generated waves can be represented by bimodal tension amplitude spectrum. Unless the first modal constituent corresponds to the surge degree of freedom, second one corresponds to random wave peak period.

Outcomes of the conducted study enable not only fundamental understanding of the mechanisms defining the mooring line tension under wide range of wind generated waves but also accurate tension force assessment in the environment.

Keywords: mooring line, random waves, spectral force amplitude, laboratory experiment

EXPERIMENTAL EVALUATION OF WAVE AGITATION MITIGATION MEASURES AT LAMPEDUSA HARBOR

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Abstract

Wave agitation within small island ports can severely hinder operational efficiency and safety, particularly during storm events. The present experimental study, conducted at the EUMER Laboratory of the University of Salento, examines design measures to mitigate wave agitation inside the Port of Lampedusa, Sicily (Figure 1a). Physical model tests have been conducted in a 29.5×28×1.5 m wave basin at a 1:50 scale, simulating severe wave conditions associated with different return periods, for a total of 32 tests. Four different harbor layouts have been assessed: the existing layout (Figure 1b) and three alternative layouts involving different combinations of breakwater extensions and quay upgrades. The layout including all proposed mitigation measures is shown in Figure 1c. Wave agitation has been assessed within the wave basin by placing 16 resistive wave gauges at different locations to measure wave characteristics for each layout (Figure 1d).

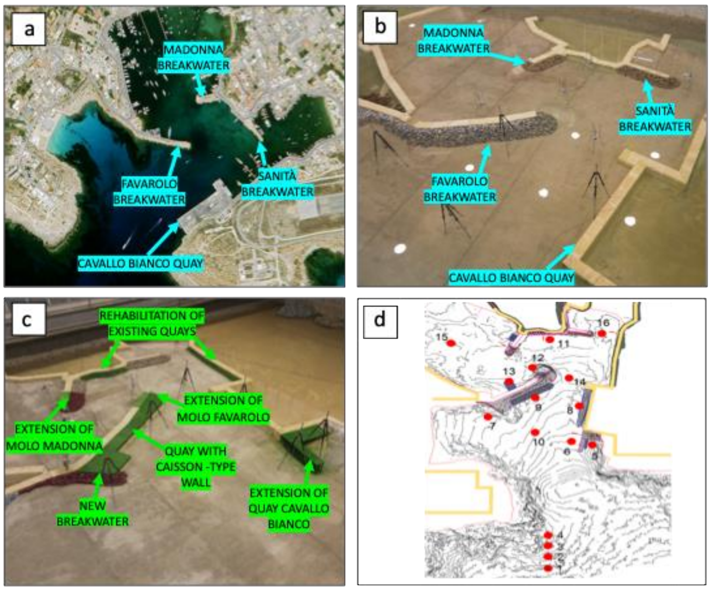

Figure 1. (a) Satellite view of the Port of Lampedusa (Sicily); (b) 1:50 physical model representing the existing harbor layout; (c) 1:50 physical model of the layout including all planned mitigation structures, painted in green and red; (d) wage gauges set-up.

The full paper will include a detailed analysis of wave agitation in all key areas of the harbor. Results will show that targeted mitigation measures can lead to a general reduction in wave agitation within the harbor, enhancing its overall functionality and safety. The results obtained in terms of wave characteristics at different locations within the experimental basin will be also valuable for the calibration of numerical models.

Keywords: wave agitation, coastal engineering, ports

NUMERICAL ASSESSMENT OF ENHANCED WAVE AGITATION IN A PORT DUE TO FAILED BREAKWATERS

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Abstract

A destructive storm on January 18-19, 2018, caused extensive damage to a commercial port in the Southwestern Black Sea Region, including the failure of two mound breakwaters near the port entrance. Guler et al. (2024) conducted a comprehensive investigation of the event, analyzing the failure mechanisms of the breakwaters based on wave modeling studies and field observations. In that prior study, the storm characteristics were estimated in deep-water and nearshore areas using the well-established numerical models WAVEWATCH III and SWAN, respectively, where a significant wave height of 7.8 m and a peak wave period of 12.4 s were estimated near the port. Additionally, SWASH simulations were employed to predict the wave characteristics inside the port under the assumption that the breakwaters remained undamaged. However, the main breakwater failed first, and the resulting enhanced wave agitation through the gap likely contributed to the subsequent failure of the secondary breakwater.

This study extends the previous investigation by conducting new numerical simulations using the CELERIS wave model (Tavakkol and Lynett, 2017) to assess the effects of enhanced wave agitation inside the port. CELERIS solves the extended Boussinesq equations using a hybrid finite volume-finite difference method. This numerical model was chosen for its ability to serve as an interactive coastal wave simulator operating on GPU, enabling simulations even faster than real time. Three primary cases are considered in the simulations: (i) undamaged breakwaters, (ii) after the failure of the main breakwater, and (iii) after the failure of both breakwaters. Additionally, interactive simulations are performed, where gaps are introduced sequentially at the failed sections of the breakwaters during runtime. The boundary conditions are directly adopted from the previous study (Guler et al., 2024), and the computational mesh is prepared using high-resolution bathymetric and topographic data.

The results are analyzed in two contexts. First, wave height distributions, wave-induced currents, and wave penetration patterns are compared across different breakwater damage scenarios to quantify the effect of enhanced wave agitation and further discuss the failure mechanisms of the breakwaters. Second, regarding advancements in wave modeling, the previous SWASH simulation is compared with the present CELERIS simulation (for the undamaged case). Moreover, the efficiency of the interactive simulations is demonstrated, which is particularly important for cases involving substantial variations in coastal structures.

Keywords: breakwater, damage, wave, storm, CELERIS

A STUDY ON THE INFLUENCE OF SEA LEVEL RISE ON WAVE OVERTOPPING AND TRANQUILITY IN SMALL FISHERY PORT

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Abstract

Imwon Port, a small and medium-sized fishing port located on the east coast of Korea, suffered extensive damage from the typhoon 'MAYSAK' in 2020. The tide level during the typhoon's attack was about 70 cm higher than the design level, leading to collisions among moored vessels and the displacement of armor blocks. In Korea, there is an increasing number of old fishing port facilities, like Imwon Port, that have been continuously damaged by high waves or typhoons. Therefore, to examine the damage phenomena occurring in small and medium port facilities and to establish countermeasures for wave overtopping and port tranquility, a three-dimensional hydraulic model test was conducted. Tidal levels were set up for the design tidal level (S.W.L +0m) at the time of port facility design as a criterion. And the tidal level (+0.7m) was reviewed as the recent damage caused by the typhoon, and the anticipated future sea level rise (+1.0, +1.3m). The experiment applied the wave height used at the time of design and the typhoon waves that occurred recently. In addition, various measures to reduce the increased wave overtopping discharge and wave energy entering the port, such as raising the crest height, installing a low crest breakwater in front of the breakwater, and extending the length of the breakwater, were examined to figure out port tranquility (Fig. 1).

The experimental results showed that the wave overtopping volume increased by about 80% compared to the design condition due to sea level rise from typhoon attack, and the wave height within the port rose by about 0.3m. Imwon Port, being a small and medium fishing port, has a relatively wide entrance width compared to its length and a shape prone to generating seiching within the port. Therefore, even if wave overtopping is effectively controlled, fluctuation of seawater surface within the port continues to occur. Hence, this study proposes measures to analyze calmness within small and medium fishing ports in the event of amplified sea level rise and wave magnitude.

Figure 1. Scene of typhoon attack and physical model test in the Imwon port, Korea

Keywords: breakwater, typoon attack, physical model test, sea water fluctuation

3. AI AND NEW TECHNOLOGIES IN COASTAL ENGINEERING

AN EARLY WARNING SYSTEM FOR COASTAL FLOOD PREDICTION USING HYDRODYNAMIC MODELLING AND ARTIFICIAL INTELLIGENCE

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Abstract

Coastal areas are increasingly vulnerable to flooding due to extreme wave events and sea-level rise driven by climate change. Effective Early Warning Systems (EWS) are crucial for enhancing resilience and enabling proactive disaster management in coastal regions. These systems often rely on numerical models to simulate flood scenarios; however, the high computational cost of these models makes real-time predictions challenging. To overcome this limitation, we implemented an Artificial Neural Network (ANN) trained on numerical model outputs, enabling rapid and accurate flood predictions. This study develops a wave-driven EWS to enhance coastal flood prediction. The system utilizes historical wave data (1993–2021) with future climate projections to simulate extreme wave conditions and sea-level rise scenarios, capturing a comprehensive range of potential flooding scenarios. To ensure diverse training data, 240 simulations were selected using the maximum dissimilarity algorithm. The selected offshore wave parameters were then used in hydrodynamic simulations conducted with the SWAN and XBeach models, which were validated before being used to generate flood patterns. Notably, the simulations accounted for vegetation's dissipative effects by incorporating habitat maps that define its characteristics and spatial distribution. The simulations outputs were used as inputs to train an Artificial Neural Network (ANN), which was designed to predict future flood events based on the relationship between offshore wave parameters and the resulting inundation patterns. The ANN was tested with unseen data, achieving R^2 values exceeding 0.95, demonstrating its strong generalization capability, and further evaluated under real-world conditions using satellite-derived flood maps. This integrated framework offers coastal managers a robust tool for disaster preparedness, enabling faster and more efficient flood risk assessment while addressing the challenges posed by climate change.

Keywords: Machine learning, artificial neural network, XBeach, disaster risk reduction, climate change.

MACHINE LEARNING IN OPERATIONAL FORECAST SYSTEMS FOR PORTS

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Abstract

These abstract details a machine learning framework for rapid, operational wave overtopping forecasts within an Early Warning System (EWS). Developed for the C2IMPRESS project (aiming to build societal resilience against extreme weather and climate change), this system focuses on Figueira da Foz harbour, Portugal, where accurate overtopping prediction is crucial for public safety.

The framework uses SWAN to propagate offshore wave conditions nearshore, considering bathymetric changes. Wave overtopping is then estimated using the SWASH model. To overcome SWASH's computational demands, an Artificial Neural Network (ANN), built with Keras (Python), is trained on extensive pre-run SWASH simulations.

The ANN's inputs are nearshore wave characteristics (from SWAN) and typical bathymetric distributions. The output is the overtopping water volumes and their impact level, providing near-instantaneous forecasts. Integrated into the existing HIDRALERTA EWS, which feeds on daily weather, wave and wind forecast provided by the Copernicus Marine Service and the European Center for Medium range Weather forecast (ECMWF), the ANN generates overtopping impact forecasts for up to 240 hours.

A video monitoring system at the North breakwater will validate the EWS, using overtopping event records. Another machine learning algorithm will be trained to recognize and extract these events form the recordings.

This combined SWAN/SWASH/ANN approach enables operational wave overtopping and impact forecasting. The Figueira da Foz methodology is adaptable for EWS development in other locations, effectively leveraging the complex SWASH model in a real-time operational setting.

Keywords: wave overtopping, SWASH model, Artificial Neural Network, Early Warning System

EFFECTIVENESS OF VR EVACUATION TRAINING FOR TSUNAMI PREPAREDNESS

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Abstract

Psychological biases are believed to significantly impact evacuation behavior, as many people may not evacuate on their own even after feeling strong tremors. Consequently, drowning in tsunamis is considered a major cause of casualties. Nakaya et al. (2018) indicated that the implementation of more comprehensive tsunami evacuation drills can reduce evacuation delays, the risk of drowning, and casualties. Meanwhile, Khanal et al. (2022) highlighted that research using XR (Extended Reality) technology is attracting attention to improve public awareness and disaster response. Therefore, this study examines the effectiveness of a VR evacuation training system.

To evaluate the effect of the VR evacuation training system, an experiment was conducted with four patterns: (1) One VR Training Session, (2) Three VR Training Sessions, (3) One On-Site Training Session, and (4) No Training. Both One VR Training Session and Three VR Training Sessions involve evacuation training in a VR environment, following a designated route. The On-Site Training involves evacuation training on-site along the designated route. In the No Training condition, no prior training is conducted. In all patterns, evacuation is conducted on-site the next day under the assumption of a tsunami.

Figure 1a shows the average evacuation distance for each training pattern, with the number of training sessions on the horizontal axis. One VR training session provides only about one-third of the effect of one on-site training session. However, conducting three VR training sessions yields an effect equivalent to One on-site training session. Using the designated evacuation site as the correct answer, Figure 1b presents the accuracy rate for each training condition. The No Training and One VR Training Session conditions showed the same accuracy rate of 25%, which was relatively low. In contrast, both the Three VR Training Sessions and One On-Site Training Session conditions achieved an accuracy rate of 100%. This indicates that Three VR Training Sessions can produce the same effect as One On-Site Training Session.

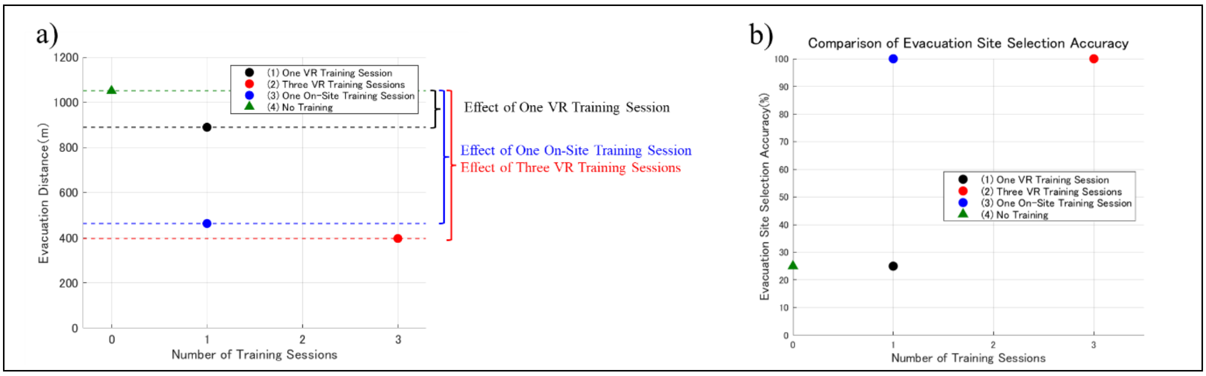

Figure 1. a)Evacuation Distance by Training Sessions, b) Evacuation Site Selection Accuracy

Keywords: tsunami evacuation, evacuation training, virtual reality, evacuation behavior

4. IMPLEMENTING NATURE-BASED SOLUTIONS FOR COASTAL RESILIENCE

NUMERICAL MODELING OF VEGETATION EFFECTS ON CROSS-SHORE MORPHOLOGY EVOLUTION

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Abstract

An advanced Boussinesq type hydro- and morpho-dynamic 2DH numerical model, describing the processes of non-linear wave propagation, wave dissipation over vegetation, sediment transport and morphology evolution is developed.
The model is based on two existing 1DH and 2DH models. The free surface flow over the vegetation is simulated using a Boussinesq model, while the flow within it is simulated by solving simultaneously a porous flow model. The model is combined with a well-confirmed morpho-dynamic submodel.
The methodology is applied to simulate the cross-shore morphological changes behind coastal areas where vegetation has been planted, as a nature-based coastal protection solution. The model is also able to simulate coastal flooding indicating the ability of the system to the reduction of coastal erosion and coastal inundation as shown in Fig. 1. Model results are compared with experimental data indicating the ability of the model to predict cross-shore morphological changes.
The main conclusion is that the attenuation of the waves results to the mitigation of coastal erosion and flooding, even in the cases of a moderate reduction in the wave height.

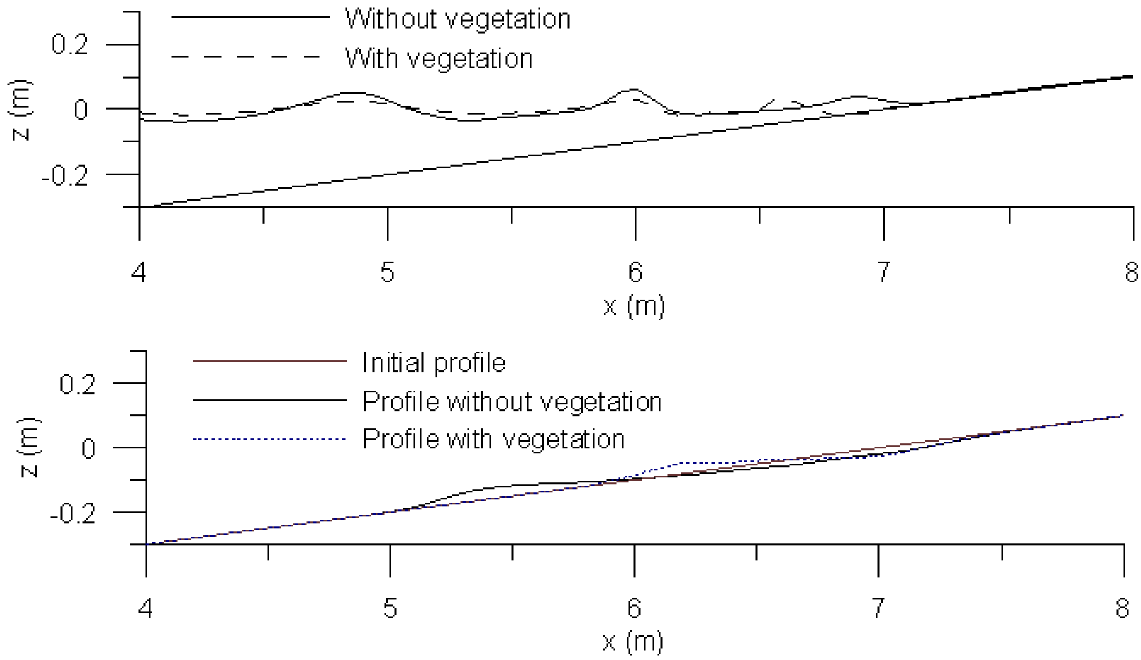

Figure 1. Wave surface elevation and runup (top) and cross-shore morphology evolution (bottom)

Keywords: Nature based solution, Coastal erosion, Coastal flooding, Numerical modeling

FROM HARD ENGINEERING TO RESILIENT SEAFRONTS: COASTAL REDESIGN IN ITALY AND FRANCE

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Abstract

For several decades, coastal protection against erosion and marine flooding relied predominantly on the construction of hard engineering structures, including groynes, parallel breakwaters, and seawalls.

Only recently, with the emergence of the "working with nature" approach and the advancement of "nature-based solutions," traditional hard defenses have increasingly given way to innovative strategies aimed at fostering resilient seafronts.

Within this framework, two case studies are presented: one along the Ligurian coast in Italy and the other near the Somme estuary in the Hauts-de-France region of France. In both cases, DHI supported the development of innovative coastal defense schemes through the application of numerical modeling.

The first case study, focusing on the coastline of Chiavari, involves the removal of existing parallel rubble-mound breakwaters and the construction of a large gravel dissipative beach through substantial structural nourishment. This intervention aims to minimize overtopping along the city's seafront promenade.

The second case study, set in the town of Cayeux-sur-Mer, followed an updated marine flood risk assessment. Rather than opting for a massive reinforcement of the existing seawall—which would have led to unsustainable landscape and economic impacts—an innovative surface drainage network was proposed to manage floodwater volumes at the top of the beach. This approach is complemented by the active/responsive management of gravel and pebble volumes across the foreshore, with the objective of reducing overtopping events.

Figure 1. Left panel: parallel breakwaters at Chiavari. Right panel: Cayeux-sur-Mer frontshore

Keywords: Mitigation of Coastal Risk, Dissipative beaches, Active Beach Management

ECOLOGICAL IMPACTS, CONSERVATION AND MANAGEMENT OF CROATIA'S GRAVEL BEACHES: INSIGHTS FROM NATURAL AND ARTIFICIAL HABITATS

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Abstract

Croatia ranks among Europe's premier summer travel destinations, celebrated for its abundance of pocket gravel beaches. However, natural gravel beaches are scarce and invaluable coastal assets. As tourism demand grows, the construction of artificial beaches has increased, often without proper consideration of local oceanographic conditions or the underlying geological structure and sediment composition. Furthermore, these interventions are increasingly affecting coastal habitats that sustain diverse biological communities and ecosystems. Additionally, current management strategies frequently overlook the biota specifically associated with gravel beaches. This knowledge gap was recently highlighted by the discovery of previously unknown endemic predatory fish species on Croatian gravel beaches, underscoring the urgent need for ecological insights to inform beach management and resource conservation. In a prior study, we identified two sympatric, specialized fish species on Adriatic gravel beaches, each inhabiting distinct microhabitats and exhibiting high sensitivity to changes in sediment composition. Remarkably, both species were also found on artificial beaches, suggesting their potential as bioindicators for monitoring and managing man-made gravel beaches. Building on this research, the CROBEach project - a collaborative effort between Croatia and Belgium - aims to deepen our understanding of gravel beaches as vital natural resources by exploring biodiversity and functional dynamics across artificial and natural beach types in the northern Adriatic Sea. Through an interdisciplinary approach, including geological analyses and biodiversity screening techniques like whole-genome sequencing and DNA metabarcoding, we will investigate the intricate interactions among gravel beach species and their recruitment patterns. Our overarching goal is to provide clear management guidelines for local decision-makers, supporting a more sustainable use of gravel beaches in the region.

Keywords: Mediterranean Sea, Tourism, Coastal habitats, Biodiversity, Coastal engineering, Habitat restoration

5. PORT ENVIRONMENTAL MANAGEMENT, BALLAST-WATER MODELLING & COASTAL HYDRODYNAMICS

PORT MONITORING TO PREVENT THE LOSS OF BIODIVERSITY

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Abstract

The idea that ballast water (BW) is a vector for the spread of non-indigenous species (NIS) dates back to 1908, although seawater has been regularly used as ballast since the 1880s when it replaced dry material. In the early 1990s, a comprehensive survey of microalgae in BW showed that ships calling at Australian ports contain a wide range of living and resting phytoplankton stages. Today we are certain that the BW of ships facilitates the transfer of NIS throughout the marine environment. An important step towards NIS management was taken in 2004 when the International Maritime Organization adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention). The BWM Convention requires all ships to have a BWM treatment system installed on board after 8 September 2024 and sets the BW discharge standard: <10 viable organisms (≥50 µm in size) per m, <10 viable organisms (10-50 µm in size) per ml and the indicator microbes below certain thresholds. However, weaknesses of this standard have already been reported as it does not require identification of species after BW treatment, does not consider organisms <10 µm in size, and the thresholds set still allow for the release of an inoculum of a species that enables successful reproduction of that species, despite the required reduction in abundance.

Port monitoring, as envisaged by the BWM Convention, is crucial for the protection of local biodiversity from the negative impacts of BW from ships and is the only real preventive approach. It enables the early detection of harmful aquatic organisms and pathogens (HAOP) that may affect the environment, human health, property or resources. In cases where HAOP are present in the port, the Convention suggests that BW intake should take place in an alternative area that does not contain HAOP or from alternative sources such as drinking water or reclaimed water. It also facilitates taking measures to eradicate or contain HAOP to prevent further spread and potentially remove specimens completely before the species becomes widespread in the region. To illustrate the true extent of potential exposure to HAOP transfer through BW, a seven-year BW discharge database for the port of Rijeka in the northern Adriatic (Mediterranean) was analyzed. The quantities of BW discharged from 2014 to 2020 ranged from 44078 m3 in 2019 to 203238 m3 in 2014. The ports of origin of the BW discharged included 116 ports from 32 countries. Although the largest and most frequent discharges were from other Croatian ports and neighboring countries Slovenia and especially Italy (as the average frequency and volume of BW discharges from 33 Italian ports in the period 2014-2020 was about 60%), the port of Rijeka was exposed to NIS from 116 ports in the Mediterranean, Black Sea, Red Sea and other seas in the Atlantic, Indian Ocean and Pacific, but also from unknown locations, as the origin of about 7% of discharges was not reported.

BWM treatment systems will reduce HAOP transfer to some extent, but prevention of HAOP transfer would be even more effective if BW uptake is prevented when HAOP is observed in port, which could be facilitated by conducting port monitoring - globally.

Keywords: Adriatic Sea, Marine policy, Invasive species, Coastal management, Biodiversity

AN INTEGRATED APPROACH TO COASTAL PROTECTION OF VULNERABLE AREAS: THE CASE OF SHIPWRECK BEACH

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Abstract

The present research focuses on the coastal protection of Shipwreck Beach in Zakynthos, Greece, a globally renowned tourist attraction, due to the presence of a shipwreck that was carried ashore by wave action back in 1980. The beach is vulnerable rockfalls threatening visitor safety, while simultaneously the wave action and rising sea-levels have resulted in significant corrosion of the ship-hull. The resarch team of LHW, as a part of an intedisciplinary team employed by NTUA, set out to understand the complex coastal processes and propose an optimal protection measure that will sufficiently protect the shipwreck from the wave action but at the same time avoid disturbing the sensitive ecosystem.

To both understand & resolve the complex coastal processes in the bay and the enclosed pocket beach, LHW followed an integrated approach combining field measurements and state of the art numerical modelling. The methodological steps undertaken are briefly summarized below:

- Bathymetric & geophysical surveying of the whole bay
- Data collection from oceanographic databases & wind stations
- Field measurements of waves and currents in deep, intermediate and shallow waters
- Validation and calibration of the integrated models of Scientia Maris
- Simulation of longshore processes with the calibrated models
- Design of beach nourishment to minimize wave runup for frequent events
- Optimization & evaluation of beach nourishment with the CSHORE numerical model

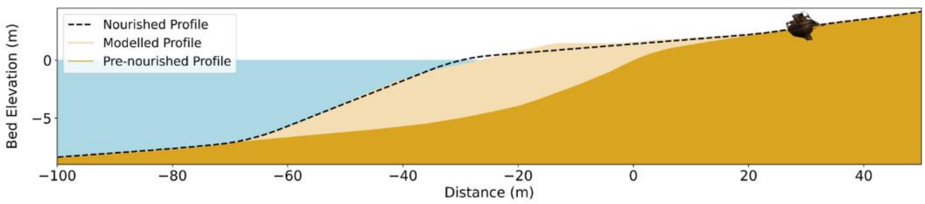

Figure 1. Modelled nourished profile after a year of wave action

The findings of this research highlight the importance of adopting an integrated approach to coastal protection. Beach nourishment emerges as a dual-purpose solution, increasing beach width while also mitigating wave runup, thereby reducing the impact of wave action on the historic shipwreck. This measure not only helps preserve the cultural landmark but also enhances beach stability, contributing to long-term coastal resilience.

Furthermore, the integrated methodology of LHW, combining extensive field measurements with advanced numerical modeling, proves invaluable in accurately capturing the complex coastal dynamics of the bay. By selecting “soft” protection measures this research provides a sustainable framework for safeguarding the natural and cultural heritage of this iconic beach.

RESPONSE OF THE NERETVA COASTAL AQUIFER SYSTEM TO TIDAL FORCING UNDER ACTIVE SEAWATER INTRUSION

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Abstract

By the implementation of melioration system during the 20th century, Neretva Valley has been transformed into the most important agricultural region on the Adriatic Sea within the territory of the Republic of Croatia. By lowering the average groundwater level as a consequence of melioration, hydraulic gradient has been increased and directed towards the inland thus leading to the occurrence of active seawater intrusion (SWI) into the coastal aquifer system. The main pathway of the seawater intrusion into the River Neretva coastal aquifer is through the Diga coastline embankment. The presence of progressive active SWI and the expected deterioration due to climate change, emphasize the need for understanding all factors contributing to the salinization of the area. This study aims to identify tidal influence as one of the dominant factors in seawater intrusion of the area and quantify its impact.

2D variable density flow and transport model has been established as a main tool to simulate active SWI through the Diga embankment and to quantify the amount of salt intruding into the River Neretva coastal system. The model has been set up perpendicular to the Diga embankment, intersecting monitoring piezometer P1 with a total domain length of 1,170 meters, of which 450 meters are located offshore. The litho-stratigraphic and hydrogeological settings have been derived from available borehole logs and laboratory determined effective porosity and hydraulic conductivity values. Boundary and initial conditions have been implemented in accordance to on-site conditions and time series provided by the continuous monitoring activities. Model calibration has been performed by using time series of piezometric head and electrical conductivity (EC) at two fixed depths in the P1 piezometer and has been validated.

Results of the coupled transient flow and transport simulation demonstrate successful model implementation. Model emphasizes the presence of active SWI with variable intensity mostly influenced by the Adriatic Sea tidal regime. The combination of nearby channel and marine boundary conditions is controlling the mean groundwater level in P1, while the variability of groundwater level in piezometer P1 is influenced by the tidal conditions with an average 1-1.5 h time lag. While the values of EC at the lower probe in P1 are stable during the model covered period, upper probe EC values show spectral similarity with external driving forces, being 3-4 h late relative to the tidal induced sea level. The established model enabled insight into quantification of the dynamic nature of SWI parameters at the site thus enabling the tool for climate change induced SWI impact analyses. The implemented model contributes to a comprehensive analysis of active SWI. Although the model is designed as a 2D and it successfully simulates the aquifer's response to tidal influence, the establishment of a 3D model and the integration of additional external factors present a next step in advancing this research.

Keywords: River Neretva, coastal aquifer, seawater intrusion, 2D model, tidal response

6. COASTAL HAZARDS AND RISK

TSUNAMI DETECTION VIA RUN-UP HEIGHT TIME-SERIES EXTRACTED FROM CCTV FOOTAGE

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Abstract

Closed-Circuit Television (CCTV) cameras are expected to provide an extensive, low-cost tsunami monitoring. We extracted wave run-up height time-series from CCTV footage and compared several shoreline detection methods based on Canny edge detection (Canny 1986)—as described by Shirai et al. (2024)—to build a robust framework for tsunami detection.

Evaluation at Hasaki Coast, Japan demonstrated that, despite variations among methods, the accuracy in capturing the key incident (0.05–0.24 Hz) and infra-gravity (IG, 0.004–0.05 Hz) components was within acceptable limits. We then applied the developed method to CCTV recordings (29.97 fps, 1920×1080) from the 2024 Noto tsunami event—recorded between 16:00 and 17:00, with the earthquake occurring at 16:10. The extracted run-up time-series included distinct tsunami components corresponded well with the tsunami run-up signal predicted by nonlinear long-wave theory (Fig. 1). Spectral analysis indicated that energy in the IG band increased by a factor of about 1.5 compared to pre-event conditions, suggesting potential influences from local bathymetry, structures, or interactions between the IG band and the tsunami band, while further research is needed to understand the mechanism.

Based on an ideal time-series constructed by linearly superimposing a theoretical offshore tsunami waveform with an ideal cosine wave representing IG noise, we evaluated several tsunami detection indices. We defined a simple signal-to-noise ratio (S/N) as the ratio of the tsunami height to the IG noise amplitude. Traditional methods—including band-pass filtering, control functions based on instantaneous slope (Bressan and Tinti 2011), and minimum description length approaches (Yamanishi et al. 2021)—were assessed, and preliminary tests using deep learning models demonstrated stable performance under low S/N conditions. Although this investigation was conducted under idealized conditions and does not fully capture the complexity of actual run-up signals, the observed behavior of each method with respect to S/N variations is expected to be informative.

Future work will focus on elucidating the behavior of coexisting tsunami and wind-wave components in actual run-up time-series and on developing robust techniques to isolate and detect tsunami signals from such complex background “noises”.

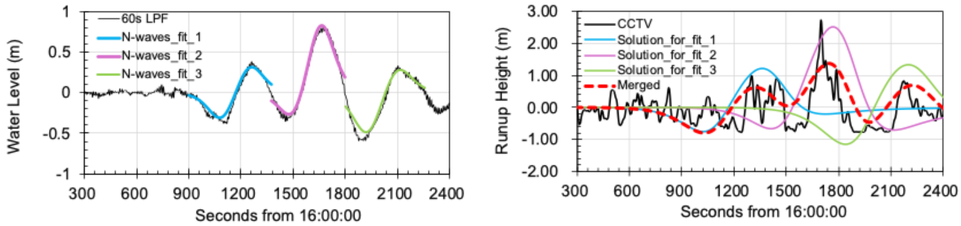

Figure 1. Left: Offshore lowpass filtered waveform observed at 12.0 m depth. Right: Comparison between the CCTV-extracted run-up time series and the Madsen and Schaffer (2010) analytical solution. “Merged” denotes the linear superposition of the first to third components corresponding to the fitted offshore components.

Keywords: wave run-up, tsunami, detection, closed-circuit television cameras

COASTAL FLOODING HAZARDS IN SOUTHERN SWEDEN: A COPULA-BASED APPROACH FOR JOINT WAVE AND WATER LEVEL

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Abstract

The Falsterbo Peninsula, situated on Sweden's southern coast, is a low-lying area highly susceptible to flooding. In 1872, the extreme storm surge known as *Backafloden* caused widespread devastation along the Swedish, Danish, and German coastlines of the South Baltic Sea. During the peak of this event, water levels reached 2.4 meters above the normal sea level in Falsterbo. This event in combination with projected sea level rise rises concerns about the potential impact of future storms. Hence, the urgency for effective preventive measures against coastal flooding.

In 2024, the municipality of Vellinge - a coastal community located on this low-lying peninsula - started the construction of a flood protection system to increase its flood resilience. To ensure the effectiveness of this measure, it is necessary to understand the main forces that could lead to its failure, namely waves and water level. While numerous studies have assessed flood probabilities (or return periods) in the Falterbo peninsula, southern areas of Baltic Sea, using univariate extreme value analysis of water levels, none have identified and characterized its dependence between waves and water levels using copula functions, which can lead in a more realistic characterization. This study aims to fill this gap by providing a probabilistic characterization of extreme waves and water levels and their interaction at the Falsterbo Peninsula using copula functions. This analysis is conducted using 36 years of data collected from two offshore sites along the coast. Extreme scenarios are defined from the probabilistic model, and wave conditions are subsequently propagated using the SWAN model. The results of this study reveal the dependence structure between extreme wave conditions and water levels, which varies along the peninsula depending on meteorological patterns. A positive correlation is observed for storms originating from the southeast, whereas a nonstandard negative correlation is found for those approaching from the west/northwest. These findings highlight the significance of accounting for the interdependence between wave conditions and water levels, particularly in depth-limited environments. Moreover, the proposed methodology is versatile and an important step towards the assessment of the probability of flooding in coastal areas at risk of inundation.

Keywords: Coastal flooding, Storms, Copula, Extreme Value Analysis

JOINT OCCURRENCE OF EXTREME STORM SURGE AND SEA WAVES ALONG THE CROATIAN COAST

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Abstract

Storm surges and extreme sea waves are major coastal flood drivers that pose a significant threat to coastal areas. The increasing impacts of climate change, including changes in storminess, mean sea level rise, land subsidence, and urbanization, are expected to exacerbate flood hazards and risks. When multiple flood drivers occur simultaneously or in close succession, they can result in compound flooding, amplifying potential impacts beyond those caused by individual drivers alone.

In Croatia, research on compound flooding has primarily focused on the co-occurrence of river discharges and storm surges, leaving other combinations of flood drivers largely unexplored. This study aims to address this research gap by investigating the joint occurrence of extreme storm surges and sea waves in the eastern Adriatic Sea. The analysis covers multiple locations along the Croatian coast, utilizing sea level and wave data from the Coastal Extremes in the Mediterranean Sea reanalysis, corrected with tide gauge measurements and numerical models using machine learning.

Storm surges and extreme waves often originate from the same atmospheric forcing, such as intense cyclones or bora and sirocco wind events. Neglecting their seasonality may lead to an underestimation of their interdependence and, consequently, the overall compound flood risk. The Croatian coast, with its distinct seasonal variations, provides an ideal setting for exploring the correlation and co-occurrence of these flood drivers. By analysing each season separately, this study offers a better understanding of joint occurrence patterns through spatially distributed correlation maps and frequency analyses at each location.

The results of this study will identify coastal areas most vulnerable to the simultaneous occurrence of high storm surges and extreme sea waves. These locations will be prioritized for future detailed assessments of compound flood risks, supporting improved coastal flood management and adaptation strategies.

Keywords: compound flooding, storm surge, extreme sea waves, coastal flood risk, seasonal variability, Croatian coast

DEVELOPMENT OF A COASTAL FLOODING VULNERABILITY INDEX: THE CASE OF ALFIOS RIVER MOUTH, GREECE

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Abstract

Coastal flooding inundation depends on a multitude of interconnected physical, social & economic drivers, with the risk and associated impacts having often destructive implications to the economy and community safety. Therefore, estimating beforehand flood-prone areas is a rather complex, yet necessary, task for effective mitigation and adaptation strategies. This study presents the development of an integrated methodology to estimate a Coastal Flooding Vulnerability Index (CFVI) for the Alfios River mouth in Pyrgos, Greece, inspired by the well-established Coastal Vulnerability Index (CVI). The CFVI was derived based on multiple parameters obtained from field measurement campaigns, renowned metocean databases, wave propagation simulations utilizing a Parabolic Mild Slope wave model and coastal profile modelling (Tab.1). Evaluation of the parameters was undertaken using spatial segments of 50 m along the shoreline for three distinct periods, a historical one and two future ones incorporating climate change impacts. To obtain the CFVI ranking, 5 classes were defined ranging from 1 (very low vulnerability) to 5 (very high vulnerability) segregating them by considering their quantiles. The results for the historical period, indicate that the most vulnerable areas are situated north of the river mouth. Climate change significantly increases vulnerability due to the combination of expected sea level rise and coastal erosion.

Table 1. Parameters used for the CVFI calculation

PARAMETER	SOURCE
Land use	CORINE
Residents / m^2	Municipality of Pyrgos, Hellenic Statistical Authority
Active profile height (m)	Topo-bathymetric survey
Significant wave height (m)	Copernicus CDS and Maris PMS
Sea level rise (mm)	Copernicus CDS
Rate of shoreline change (m/day)	Copernicus CDS, PMS & CSHORE
Marine bed slope (%)	Topo-bathymetric survey
Land slope (%)	Topo-bathymetric survey
River proximity (m)	GIS processing
Number of compound events	Copernicus CDS

The findings of this research highlight the importance of adopting an integrated approach to coastal flooding vulnerability, focusing on prevention and preparation combining high fidelity numerical simulations, field measurements and data from metocean databases. The stepwise methodology and developed index can readily be applied in flood-prone areas worldwide.

NUMERICAL MODELLING OF STRATIFIED FLOW IN THE CANAL ISTANBUL AND THE BOSPHORUS UNDER THE CLIMATE CHANGE IMPACT

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Abstract

The Bosphorus (Fig. 1a) is a natural waterway located between the Black Sea (BLS) and the Sea of Marmara (SM) and presents a stratified—mostly two-layered—flow structure (Fig. 1c). It is the only sea gate of the BLS countries to the open seas (e.g., the Mediterranean) in the south. The strategic waterway's highly variable flow structure depends on the region's meteorological and hydrological conditions.
The Turkish government has recently proposed an artificial canal named The Canal Istanbul (CI), which aims to improve navigational safety by reducing shipping traffic in the Bosphorus. The new channel is expected to affect the hydrodynamics in the Bosphorus and the surrounding region. In this study, the possible effects of the twin-strait configuration on the hydrodynamic behaviour of both the artificial and natural straits were studied via numerical modelling employing Delft3D. The model results revealed that the annual flow structure is mainly characterized by one-layered southward BLS flow in the CI with a mean current velocity of around 0.8 m/s (Fig. 1b). Only near the southern entrance of the CI is the northward SM flow observed (Fig. 1b). The two-layered flow could only develop near the southern entrance of the CI with mean velocities around 0.1 - 0.2 m/s. As a result of the integration of CI into the model area, significant changes in the hydrodynamics of the Bosphorus have been observed (Fig. 1c). Due to CI, the water level difference between the Bosphorus's two entrances decreased by 10-20 cm, and velocities at certain locations decreased by around 0.5 m/s.
In addition, the possible response of the hydrodynamic structures of these artificial and natural straits to their driving conditions in the future is also studied, considering two climate change scenarios (RCP 2.6 and RCP 8.5). The water levels, current velocities, layer thicknesses, and seasonal behaviour in the waterways changed significantly depending on the climate change scenarios.

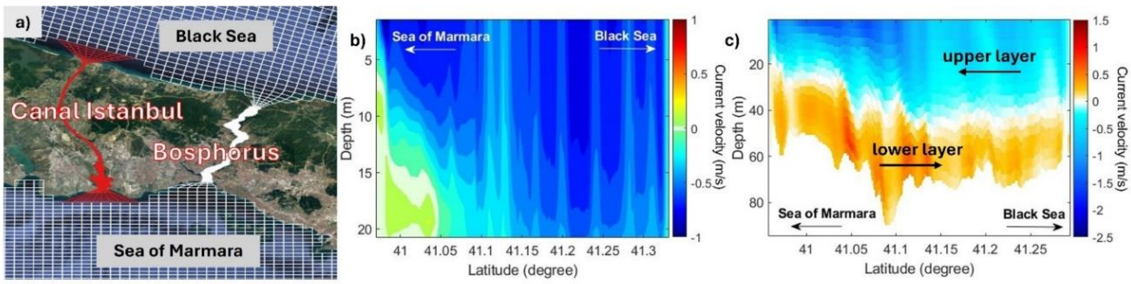

Figure 1. a) The computational mesh of the Bosphorus and the Canal Istanbul, b) Velocity profiles of the Canal Istanbul, c) Velocity profiles of the Bosphorus

Acknowledgements: This research is supported by the Scientific and Technological Research Council of Turkey (TUBITAK) with project number 222M240.

Keywords: sea strait, artificial canal, Black Sea, Sea of Marmara, RCP 2.6, RCP 8.5

GLOBAL ASSESSMENT OF TSUNAMI AND STORM WAVE SIZES USING COASTAL BOULDERS

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Abstract

Coastal boulders transported by past tsunami or storm waves have been reported worldwide. These boulders can be used to estimate recurrence intervals of past tsunami or storm wave hazards up to several thousand years ago in an age when historical and observation records were not preserved. In the case of a boulder, the intensity of past coastal waves can be estimated by calculating the hydraulic wave force which can move a boulder. Here, we investigated the sizes of tsunamis and storm waves using coastal boulders distributed across the world's coasts.

First, we proposed empirical relations to estimate the minimum tsunami or storm wave heights to move a boulder. We conducted tsunami and storm wave simulations over the ideal reef, planar, and cliff topographies using CADMAS-SURF/3D (Arikawa et al., 2005). CADMAS-SURF/3D is a numerical wave tank flume model developed for an advanced maritime structure design. We then calculated wave pressure acting on a boulder over the shoreline under various topography and input wave conditions. We also output water depth on the shoreline when maximum wave pressure was calculated. Using the calculated pressure and water depths, the empirical relation which can estimate wave pressure acting on a boulder from the water depth was proposed. Using the relation, we proposed the formula to estimate minimum tsunami and storm wave heights that can be calculated from the boulder's density and dimension.

We then collected data on the location, size, and dimension of coastal boulders from a literature review and estimated the minimum wave height necessary to move the boulders using our proposed formula. From these results, the locations where past coastal natural hazards happened and future risks of coastal natural hazards were discussed.

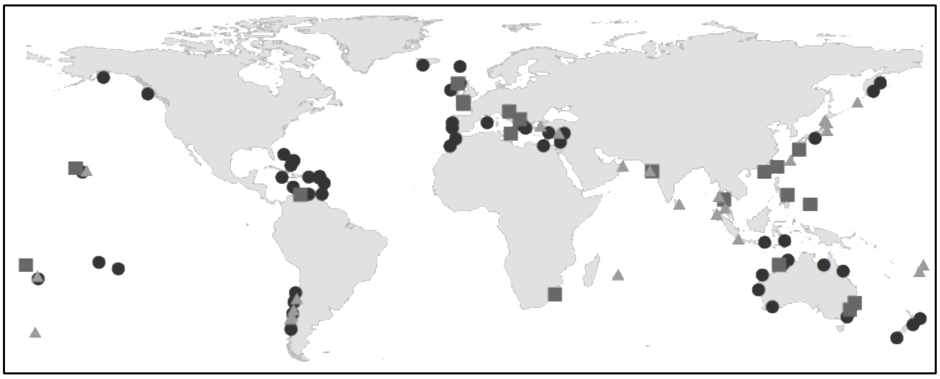

Figure 1. The distribution of coastal boulders. The figure was modified from Watanabe et al. (2020). The triangle, square, and rounded marks in the figure are the location of the tsunami boulder, storm boulder, and the boulders whose origin has not been identified.

Keywords: tsunami, storm wave, coastal boulders, numerical simulation, coastal natural hazards

7. SEA DYNAMICS & OFFSHORE RENEWABLES

STORMS IN 1982–2023 IN THE CASPIAN SEA

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Abstract

The wave climate of the Caspian Sea has been notably underrepresented in existing scientific literature, highlighting a crucial gap in our understanding which is necessary for coastal management and design in the world's largest inland sea. We are modelling waves with SWAN model forced with ERA5 modelled wind data in 1982–2023. The model has temporal and spatial resolution of 1 hour and 2.5 km and has been checked with previously modelled results in the scientific literature and available, albeit scarce, measurements and observations for the area. The long-term changes of the average wave conditions in the past were analyzed and assessed for both average values and the frequency of occurrence of different significant wave heights and wave periods over time periods of 30 years. Our findings demonstrate that the model adeptly captures the essential statistical characteristics of the wave climate in the Caspian Sea, including the occurrence and peak magnitudes of extreme significant wave heights. However, estimated extreme wave heights considerably differed from those described by previous authors. Also, our results are showing that the wave climate in the northeastern sea may be very severe. For this reason, we are looking more closely the development of storms in time. It might be that eastern storms are longer than the others. Interestingly, it can be seen that only 9 storms have caused very high waves in computation nodes which cover 97% of the sea.

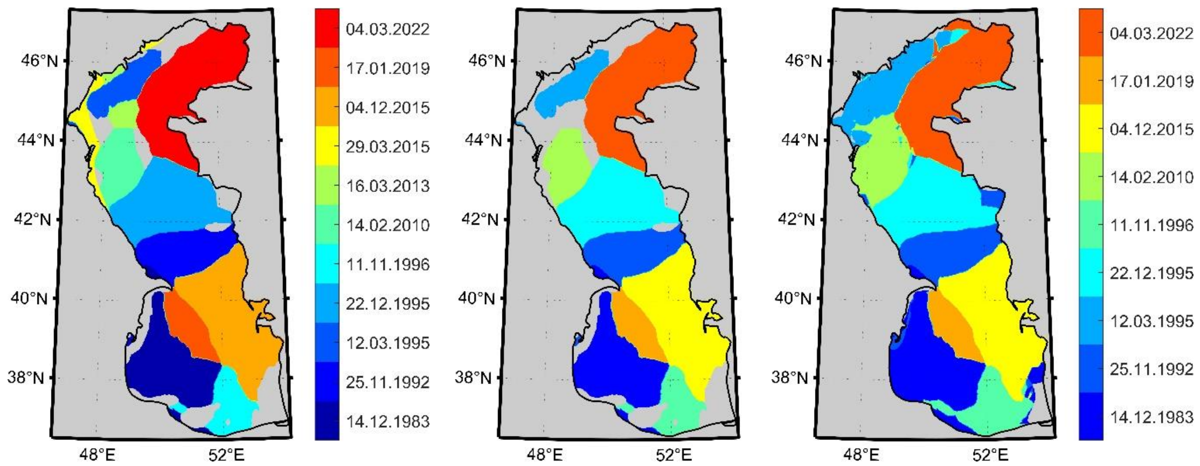

Figure 1. 11 storms which cause maximum Hs in 87.43% of the Caspian Sea (left panel). Middle and right panel: 9 storms which cause maximum Hs in 82.21% and in 97.49% of the Caspian Sea if Hs less than 10% of maxima in the cells are accounted for

Keywords: SWAN, ERA5, wave climate

THEORY AND MODELLING OF INFRAGRAVITY WAVES

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Abstract

InfraGravity (IG) waves are surface water waves with periods commonly defined in 30 to 300-second range. Unlike waves of higher frequencies, they are not generated through direct wind forcing. While there are many proposed mechanisms (e.g. moving breakpoint, gusts, synoptic cells) their primary generation mechanism is nonlinear wave-wave interactions in coastal regions. These regions are also where their impacts are most pronounced. They are of great importance in sediment transport, can amplify the storm surge magnitude (causing flooding), and can lead to harbor resonances.

IG waves are difficult to measure, and there is a significant lack of data, especially regarding long-term measurements, for use in design of harbors and shoreline management. For this reason, the magnitudes and properties of IG waves are commonly estimated through modeling. However, unlike wind waves, they can contain a significant amount of energy in three different regimes of dispersion relation: free waves, bound or forced waves, and edge waves. This makes use of stochastic models (such as SWAN or WAVEWATCH III) for their modeling and forecasting a challenging endeavor.

In this work, we present new nonlinear models of IG wave generation over variable bathymetry, with a special focus on the effects of the nonlinear dispersion relation and the fully directional properties of the IG wave generation and reflection. We focus on deriving the equations in forms suitable for implementation into operational stochastic models; however, we also verify the results using a Boussinesq-type model. The capabilities of the model are tested using reanalysis data and in-situ measurements.

Keywords: infragravity waves, stochastic modelling, nonlinear interactions, erosion, harbor resonance

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HYBRID WAVE ENERGY CONVERTERS BASED ON OWC AND OVERTOPPING MECHANISMS: NUMERICAL MODELLING

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Abstract

This work presents the development of the O2WC concept, a hybrid Wave Energy Converter (WEC) based on combining the Oscillating Water Column (OWC) and the Overtopping Device (OTD) approaches. The studied WEC embodies a classical OWC device, in which the water column is hydraulically connected to a second oscillating column. From the second oscillating column, water overtops into a reservoir located above the mean sea level. Both an air turbine and a low-head water turbine can be used to convert the wave energy. In the hybrid O2WC concept, the maximum airflow rate and air pressure in the OWC chamber are reduced, possibly aiding the safe functioning of the air turbine, and allowing to exploit the excess of energy instead of dissipating it through bypass valves.
Scale-model tests of such a concept were conducted in the wave flume of LABIMA (University of Florence), both in 2018 and in 2021, as documented in Cappietti et al., 2018 and Simonetti et al., 2022. Laboratory tests show that the decrease in the primary conversion efficiency of the OWC component of the device caused by the decreased air pressure in the OWC chamber can be partially compensated by the additional energy stored in the overtopping chamber of the O2WC device. Overall, in the laboratory tests, the O2WC device has captured width ratio values ranging between 0.3 and 0.7.
In the present work, a numerical model, validated with the available laboratory data, was used to extend the set of geometry configurations of the device and incident waves tested, with the aim to further optimize the geometry. Numerical modelling consisted of Computational Fluid Dynamics (CFD) simulations, performed in the OpenFOAM® open-source software package. Two phases, water and air, Volume of Fluid (VOF) solver was used. The sensitivity of the O2WC performance to the variation of the principal design parameters was investigated. The effectiveness of this kind of hybrid WEC, in terms of capture width ratio associated to both the oscillating water column and the overtopping mechanisms, is presented and discussed under the action of regular waves of different height and period.

EXPERIMENTAL ANALYSIS OF RIPRAP SCOUR PROTECTIONS FOR HYBRID OFFSHORE FOUNDATIONS

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Abstract

A critical aspect of the offshore wind sector is the cost-effective design of foundations, which can represent a significant portion of the project's total investment. While scour around monopile foundations has been extensively studied, knowledge gaps persist for other foundations with more complex geometry, particularly jackets and hybrid structures – e.g., offshore wind combined with wave energy converters (WEC). This paper aims to provide an overview and an experimental study on the performance of riprap scour protection solutions for monopile and jacket foundations as a step for creating a new database of scour tests. During the experimental tests, using a geometric scale of 1:50 and performed using waves and currents, an OSWEC – a simplified version of an Oscillating Surge Wave Energy Converter – was also integrated into both foundations, as the impact of hybrid offshore structures on scour and in scour protection's performance is an interesting topic of discussion regarding the optimization of offshore wind technologies and a considerable knowledge gap in the literature. Results showed a reliable performance of the scour protection for both the monopile and jacket model but also highlighted the influence of the WEC by demonstrating the severe scour damage induced by enhanced flow patterns, such as downflow, horseshoe vortices, streamlined contractions, etc., that jeopardize the protection's performance, despite a promising potential to mitigate wave transmission. This work advances the understanding of the scour phenomena and countermeasures around complex and hybrid offshore wind turbine foundations. It gives insights and shows that developing new, optimized, and more efficient scour protection solutions for the next-generation offshore renewable energy systems is an attractive opportunity for future research in the scientific community.

Keywords: Offshore Renewable Energy, Scour Protection, Monopile, Jacket, Wave Energy Converter, Hybrid Foundation

SOME NUMERICAL MODELLING OF THE SEASONAL STRATIFICATION OF THE GEMLIK BAY, MARMARA SEA, TÜRKIYE

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Abstract

The water exchange between the Aegean Sea and the Black Sea occurs through a two-layer flow system within the Marmara Sea (Chiggiato et al., 2012; Sunar et al., 2022; Yalçın et al., 2017). These layers are typically separated by a pycnocline located at approximately 25 meters depth, which can be disrupted by strong wind-induced recirculation leading to upwelling events (Beşiktepe et al., 1994; Chiggiato et al., 2012; Mutlu et al., 2023). Similar dynamics are observed in the Gemlik Bay, a 35 km long semi-enclosed basin located in the southeastern Marmara Sea. However, current available models are not able to accurately reproduce stratification patterns shown by measured data.

In this study, simulations are conducted using Delft3D, for the period from January 2023 to September 2023, capturing both winter and summer seasonal variability in hydrodynamic and stratification processes. The Delft3D model, configured with a horizontal resolution of 100 meters and 30 vertical layers, was initialized using a hybrid approach, with water level and velocity data taken from the Copernicus model. The bathymetry used in the model was obtained from EMODnet. The model was set up with an open boundary on the western side, where Riemann invariants were applied to define flow conditions. To obtain a proper simulation of stratification patterns and vertical profiles of salinity and temperature, in-situ measurements provided by RV TÜBİTAK MARMARA are used to define the corresponding boundary condition: interpolated salinity and temperature profiles were imposed, based on seasonal data for January, April, and August. The model was forced with hourly wind and surface heat flux data obtained from the ERA5 reanalysis dataset, providing realistic atmospheric forcing throughout the simulation period.

Delft3D was calibrated using water surface elevation data from the Copernicus model as shown in Figure 1. The results are compared with Copernicus model outputs and seasonally measured in-situ data on salinity and temperature showing that Delft3D more accurately captured the halocline and thermocline structures, closely matching the measured data, outperforming the Copernicus model in representing vertical flow stratification.

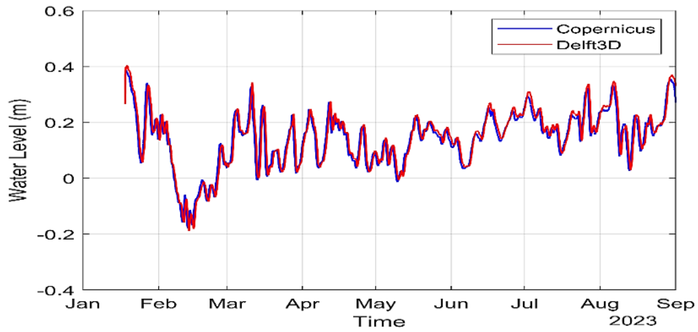

Figure 1. Water level comparison between Delft3D and Copernicus

Keywords: hydrodynamic modelling, stratification; halocline, circulation, pycnocline, Delft3D

8. POSTER SESSION

ANALYZING SPILLS IN THE PORT OF GENOA: HYDRODYNAMIC AND CONTAMINANT TRANSPORT FOR METE-OCEAN SCENARIOS

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Abstract

According to the EMSA report, ports are the area where most marine accidents occur. This happens because, ports are high-traffic zones where vessels maneuver in confined spaces, increasing the likelihood of collisions, groundings, and spills.

This study aims to understand the impact of the port traffic on the surrounding marine environment, by developing a numerical model for the simulation of the dispersion of substances released within the port. The study case is the port of Genoa, one of the most important in Europe, thanks to its strategic position in the upper Tyrrhenian coast.

The method proposed consists of collecting and analyzing all the environmental variables that play a role in generating the currents in the domain. Through a clustering algorithm, a manageable number of scenario is identified and used to force a high resolution hydrodynamic model. The velocity fields are validated by comparing the model water level, with water level measured inside the port. Finally, through a separate model, the dispersion of different type of Oil and HNS is analyzed. To support the recovery strategies, two key analysis are implemented and the results are shown in the Estimation Time of Arrival and the Hazard plots (Figure 1).

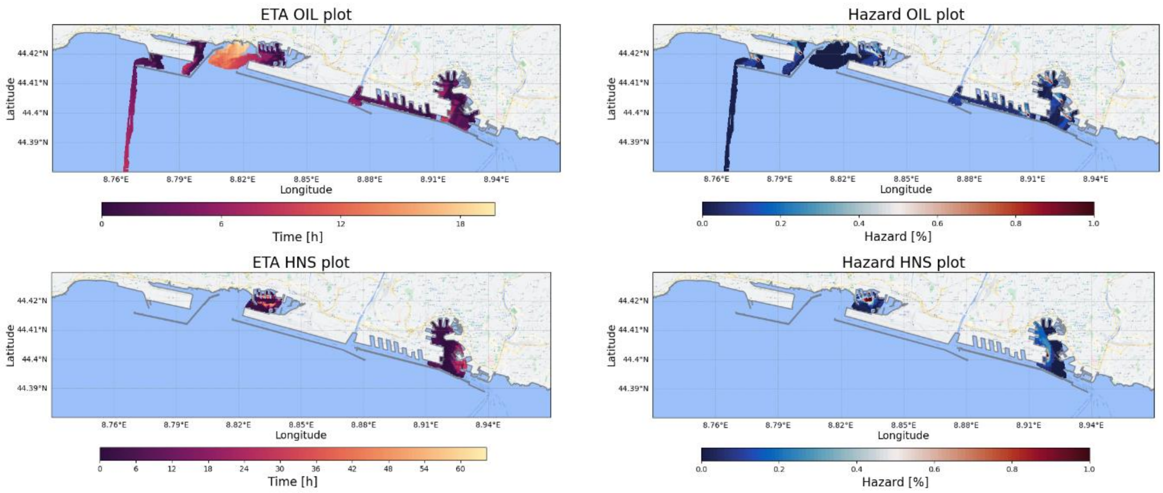

Figure 1. Estimation Time of Arrival (left) and Hazard (right) plots for Oil (top) and HNS (down) spills.

The results reveal that the contaminants, with the exception of one metocean scenario, remain inside the port's boundaries. This can cause a significant water quality degradation, potentially affecting the local ecosystem, but it also decreases the risk of a widespread contamination, simplifying the recovery efforts.

A PRACTICAL APPROACH IN WAVE RUN-UP MODELING WITH A 3D NUMERICAL WAVE MODEL

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Abstract

A 3D numerical analysis of surface gravity wind waves dynamics was carried out with a focus on the processes that occur in the wave breaking and swash zone. In the case of relatively short waves, i.e. characteristic spectral wave characteristics $H_S \approx 1$ m and $T_P \approx 4$ s, the computational grid for the application of the 3D wave model should have a very high spatial resolution (≈ 0.5 m. This makes the implementation of numerical simulations covering a wider coastal zone very demanding in terms of the time required for the calculation. Therefore, this paper presents a methodology in which the calculation execution time is significantly reduced due to the adoption of an appropriately extended peak spectral period T_P, without compromising the accuracy of the calculated wave reach along the beach profile. The data obtained from measurements on the Ploče beach in Rijeka (wave recorder in front of the beach and video camera on the beach) were used for the parameterization of the 3D wave model and validation of the established methodology.

Based on the measured *R2%* values, the corresponding extended peak spectral period $T_{P\text{-}SIM}$ was calibrated, with which the calculation execution time in the model with a coarser calculation grid was significantly reduced. For the two analyzed situations, the extension of the real-registered wave period T_P is 10% and 35% ($T_{P\text{-}SIM} = K_{Tp} * T_P$; $K_{Tp} = 1.1, 1.35$, respectively) and the calculation time was reduced by 20 and 74 times. Shorter peak periods T_P require larger values of the extension coefficient K_{Tp}, which also depends on the choice of the calculation grid density.

In order for the proposed methodology to take on concrete practical significance (defining the extension coefficient K_{Tp} for a wider range of T_P and incident wave angles), it is necessary to significantly expand the number of analyzed situations, which is the intention to do in the continuation of the research.

Keywords: Wave run-up, non-hydrostatic 3D wave model, video monitoring

CHANGING CAPACITY OF BEACHES OF KUSADASI, TURKIYE CONSIDERING SEA LEVEL RISE

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Abstract

The irreversible physical, environmental and socio-economic damages of uncontrolled recreational activities, changing climatic factors, sea level rise and shoreline evolution have been drastically affecting tourism quality and available recreational areas. It is recommended that the uncontrolled usage of beaches should not exceed a certain level, defined as carrying capacity, considering the long-term protection of coastal areas. In this study, it is mainly aimed to determine the physical and real carrying capacities of natural, urban and non-urban coasts of city of Kusadasi using the Cifuentes (1992) method. Region-specific physical features and climatic conditions limiting the beach use are analyzed and temperature, precipitation, wind speed, cloud cover and shoreline evolution correction factors are applied to assess the present Real Carrying Capacities (RCC). Also, scenarios of different climate models are adapted to the study area to predict the possible future impacts of climate change on recreational use. The Coastal Area Vulnerability Model (CVI-SLR) is integrated into the existing methodology to consider the physical parameters (sea level rise rate, coastal slope, wave height, tidal range and sediment budget) and parameters formed by human effects (coastal protection structures and reduction of sediment supply) in the evaluation of the coastline (Ozyurt & Ergin 2010). According to the results, the carrying capacities of all of the beaches are decreased by a ratio of two thirds mostly caused by excessive sunshine. Future predictions shows that almost all of the Kadinlar and a large part of the Pamucak and Davutlar beaches will be lost in the next 100 years. The sustainability of beach activities in Kusadasi will be affected by loss of beach area and consequently the loss of visitation quality because of the crowding. The results show that an effective solution needs to integrate both visitor management plans and shoreline management strategies for beach areas.

Keywords: Beach Carrying Capacity, Coastal Zone Management, Sustainable Tourism, Shoreline Evolution, Sea Level Rise, Climate Change

EXPERIMENTAL INVESTIGATION OF TSUNAMI INTERACTION WITH AN EMBANKMENT STRUCTURE

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Abstract

Tsunamis propagating through rivers can intensify inland flooding and cause severe damage to infrastructure and communities. As the wave enters a river channel, interaction with the countercurrent alters its form, resulting in either an undular bore—a leading wave followed by smaller waves (whelps)—or a breaking bore, marked by a sudden water level rise without trailing waves (Tsuji et al., 1991; Yasuda, 2010; Whuppukondur and Baldock, 2022; Ari Guner et al., 2024). These complex hydrodynamic behaviors can increase the destructive potential of tsunami wave in riverine environments. To reduce these impacts, embankments can be designed to dissipate wave energy before it propagates further upstream. However, research on tsunami-embankment interactions remains limited. This study aims to enhance the understanding of embankment performance under tsunami conditions through physical model experiments.

The experiments were carried out in a channel at Yildiz Technical University's Hydrodynamics Research Laboratory, designed to simulate tsunami propagation in riverine environments. The channel is 32.9 meters long, 0.6 meters wide, and 0.9 meters deep. A pneumatic tsunami generator, placed at the downstream end, created through-led N-wave, while an adjustable water supply at the upstream end. The through-led N-waves used in this study were previously generated and analyzed by Ari Guner et al. (2024), considering three bore strengths (0.24, 0.48, and 0.69), calculated as $\alpha = a^+/h$ (where a^+ is the positive wave amplitude). Experiments were conducted at two water depths (20 cm and 25 cm) under still-water and local flow conditions with the discharges ranging from 16 to 50 l/s. These predefined waves have been used to examine their interaction with embankment structures. Three different embankment designs have been tested: (E1) a rock armor layer with a gravel core, (E2) a fully gravel embankment, and (E3) a gravel embankment with an impermeable plate in the center. The embankments were analyzed both as submerged structures and with their crests at still water level (SWL), affecting wave transmission, reflection, and flow patterns. Preliminary results show that embankments influence wave transmission and energy dissipation, with variations depending on structure type and submergence level. However, further experiments are ongoing. The findings of this study will contribute to tsunami mitigation strategies in riverine environments, supporting the design of flood-resistant infrastructure.

Keywords: wave, river, physical modelling

LONG-TERM ANALYSIS OF WAVE CLIMATE AND SHORELINE CHANGES ALONG THE CENTRAL GULF OF THAILAND: A CASE STUDY OF SAMUT SONGKHRAM PROVINCE, THAILAND

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Abstract

This study examines the long-term wave climate and shoreline changes in Samut Songkhram Province, located in the central Gulf of Thailand. The analysis focuses on understanding the impacts of natural and anthropogenic factors on coastal dynamics over the past three decades. Using ERA5 reanalysis data (1995–2023) for wave parameters and Landsat imagery (2000–2024) for shoreline mapping, the study employed statistical trend analysis and the Digital Shoreline Analysis System (DSAS) to quantify changes in wave climate and shoreline positions. The study area includes four sub-districts—Bang Kaeo, Bang Chakreng, Laem Yai, and Khlong Khon—selected for their ecological and economic significance. The results reveal spatially variable shoreline trends. Bang Kaeo showed a net erosional trend (-1.48 m/year), while Bang Chakreng and Khlong Khon experienced net accretion (+0.53 m/year and +2.16 m/year, respectively). Laem Yai demonstrated the most dynamic changes, with extreme erosion rates reaching -123.43 m/year and accretion rates up to +90.61 m/year. Significant wave height (Hs) exhibited a slight upward trend over 30 years, with pronounced variability during the southwest monsoon, which correlates with increased shoreline erosion. Monthly wave rose diagrams revealed that wave direction predominantly originated from the southwest during monsoon seasons, intensifying wave energy along the coastline. Correlation analysis highlighted a strong link between wave energy and shoreline dynamics, emphasizing the influence of wave climate on coastal geomorphology. For instance, periods of higher wave energy aligned with increased rates of erosion, particularly in Bang Kaeo and Laem Yai. Conversely, calmer wave periods facilitated accretion in Khlong Khon. These findings underscore the dual role of natural processes and human activities, such as coastal development and aquaculture, in shaping the region's shoreline changes. This study provides a comprehensive assessment of the coastal dynamics in Samut Songkhram, offering valuable insights into the impacts of climate change and human interventions. The results contribute to developing sustainable coastal management strategies, emphasizing the need for targeted erosion mitigation measures, preservation of mangroves, and adaptive planning to enhance resilience against future environmental challenges. By addressing both scientific and practical concerns, this research supports evidence-based decision-making for the long-term sustainability of coastal communities in the Gulf of Thailand.

Keywords: Shoreline changes, coastal erosion, climate change, DSAS, samut songkhram

NATURAL HAZARD EVENTS IN MEDITERRANEAN AREAS: A MULTI-HAZARD AND MULTI-LEVEL ANALYSIS

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Abstract

Natural hazards are triggered by catastrophic phenomena such as extreme weather events, earthquakes, volcanic eruptions, wildfires, landslides, etc., which often have serious consequences for the territory, structures, and infrastructures and are lethal for humans. Therefore, it is fundamental to assess, plan, and manage, together with the knowledge of the trigger mechanism and their modeling, the design phases of adequate and sustainable mitigation measures.

From this point of view, Calabria is an interesting case study for its geomorphological, climatic, hydrological, and anthropic peculiarities, which make it extremely susceptible to natural hazard events, either single or overlapping, e.g., earthquakes with simultaneous extreme rainfall events, or consequential, e.g., an earthquake followed by a landslide, as happened in the past. The paper analyses the natural hazards typical of the Mediterranean area, such as earthquakes, tsunamis, floods, and fires, and considers climate change that could increase their frequency and intensity. The analysis was carried out by means of a multi-hazard and multi-level approach. Level 0 concerns the cognitive framework of historical events that the Calabria region has experienced during its history. Level 1 analyses the most catastrophic historical events. Level 2 defines hypothetical event scenarios: e.g., the occurrence of tsunamis or historical floods with the current degree of anthropization of the territory. Levels 3 and 4 provide a rapid and detailed analysis of the effects generated by these scenarios, respectively. Finally, level 5 analyses the triggering mechanisms of such events and the probability of joint events occurring.

Regarding Levels 0 and 1, in the autumn season, the sea temperature often remains high compared to the averages for this period. This condition can favor the formation of intense atmospheric disturbances like hurricanes (called Medicane, Mediterranean Hurricane) such as those that occurred between 31 October and 2 November 2015. The Calabrian climatic peculiarities also favor the formation of atmospheric disturbances which, even if they are not Medicane, can still be particularly extensive, intense, and persistent such as the events that occurred in 1951 and 1953, which are the most important of the last 100 years. The presence of mountainous reliefs very close to the coast favors persistence due to the orographic effect. Furthermore, there is a high-density seismic risk in all the land territory and an active fault that passes through the Strait of Messina. Therefore, Calabria is susceptible to seismic events that could interest both land and seabed, and this leads to the generation of a tsunami. Among these, the most intense was that of 1908 with a magnitude of 7.1, and that of 1783 with a magnitude of 6.9. Finally, Calabria is also particularly subject to fires such as those of summer 2021.

Keywords: Natural hazard events, multi-level analysis, multi-hazard analysis, earthquakes, tsunamis, floods, wildfires

WAVE ENERGY TRANSFORMATION INDUCED BY HEXAGONAL "SEAHIVE" STRUCTURES TO BE USED AS A BASE FOR CORAL OUTPLANTING

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Abstract

Various methods have been explored to mitigate coastal erosion, with recent studies focusing on the physical properties of coral reefs due to their natural ability to dissipate wave energy in nearshore environments. The Defense Advanced Research Projects Agency (DARPA) has launched the "Reefense" project, which seeks to replicate the protective function of coral reefs through a hybrid approach that combines living corals with artificial structures. This nature-based engineering strategy integrates a concrete breakwater foundation with coral outplanting to enhance wave attenuation while fostering an ecological habitat.

The University of Miami, in collaboration with other institutions, is part of the "X-Reefs" team within Reefense, focusing on coral reef restoration off the coast of Florida. The primary objectives of this initiative include shoreline protection, ecosystem enhancement, and safeguarding military infrastructure. A key component of the project is the "Seahive," a modular hexagonal perforated structure designed to be stacked and arranged in various configurations. In nearshore environments, porous breakwaters often experience sedimentation within the Seahive, and biological interference, such as algae growth, which can alter their porosity and wave dissipation capabilities over time. These effects can be simulated in laboratory settings to assess how structural perforations may become obstructed and impact overall performance.

This study evaluates the effectiveness of scaled Seahive models under intermediate wave conditions. The performance metrics include porosity and wave energy dissipation, with comparisons between fully open and partially obstructed structures to simulate real-world marine debris accumulation.

Experiments were conducted in the University of Miami's SUSTAIN tank (23m x 6m x 2m) at a 1:10 scale to replicate the hydrodynamic effects of coral reefs in shallow water. Key experimental design considerations included sensor selection and positioning. Six HR Wallingford "Wave Probes" (HRWG-0106) and four OSSI-010-008 Wave Staff III vertical wave wires were deployed to measure wave surface elevation under varying conditions. The wave probes were arranged in an array, with three positioned before and three after the structure, while the wave wires were used to validate the probe readings, with two placed before and two after the Seahives.

To securely position the Seahives within the SUSTAIN tank, a 12 cm-tall wooden deck (3.65m x 2.43m) was constructed, allowing the structures to be bolted in place and withstand incoming waves. The material used to obstruct the Seahive openings was made of clear plastic simulated and sediment and debris accumulation. Perforations were obstructed 25%, 50%, and 100% and compared to a fully porous Seahive.

Keywords: Coastal erosion, Wave energy dissipation, Coral reefs, Nature-based engineering, Hybrid breakwaters

WAVEMOTION EFFECTS IN MICROPLASTIC SEDIMENTATION

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Abstract

Plastic pollution in marine environments has become one of the major environmental issues of the last century. Plastics, due to their properties, can persist in water for hundreds of years, gradually fragmenting into microplastics (MP). When their density is higher than that of water, they tend to settle and may enter the marine food chain through ingestion by marine fauna. Studying the phenomena that affect MP dynamics is essential for identifying potential accumulation hotspots on the seabed. The present study examines the sedimentation of five MP particles with different shapes and densities under varying hydrodynamic conditions, through a laboratory experimental campaign. The experiments were conducted in an 18-meter wave flume. The MPs were tested under three different hydrodynamic conditions: HC-1: still water, HC-2: regular waves with a wave period *T=1 s* and wave height *H=0.12 m*, HC-3: regular waves with a period of *T=1 s* and wave height *H=0.15 m*. For each sample, at least ten particles were released a few centimetres from the surface and monitored via video, analysed using the Blob Analysis technique. Tab.1 shows the characteristics of the tested MPs and the results in terms of settling velocity for conditions HC-1 and HC-3.

Table 1. Sample name (*id*), material, shape, density (ρ_p), maximum element size (*d*), drag coefficient (C_D) and settling velocity measured for HC-1 and HC-3 conditions.

id	*Material*	*Shape*	ρ_p *[g/cm³]*	*d [mm]*	$C_{D,HC-1}$	$w_{s,HC-1}$ *[m/s]*	$w_{s,HC-3}$ *[m/s]*
NB01	PLA	cube	1.260	5	1.33	0.1384	0.1383
NB02	PLA	cube	1.106	5	0.68	0.1248	0.1120
NB03	PLA	cube	1.034	5	0.90	0.0674	0.0608
NB04	PLA	cylinder	1.260	5	0.94	0.1459	0.1440
NB05	PLA	sphere	1.260	5	0.86	0.1684	0.1528

Fig.1 shows the results in terms of NB01 trajectory tracking for HC-1 and HC-3.

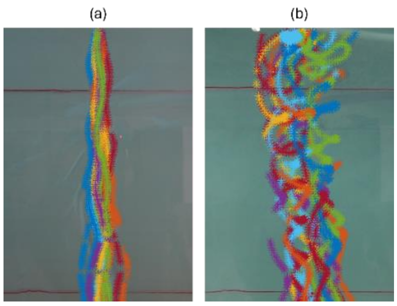

Figure 1. (a) Sedimentation trajectories of sample NB01 for HC-1 condition; (b) Sedimentation trajectories of sample NB01 for HC-3 condition.

The results show that settling velocity increases with density. For samples with the same density, it decreases with hydrodynamic resistance (C_D). In the presence of waves, settling velocity decreases for all particles, with a more pronounced effect on low-density ones, as they tend to be trapped by wave orbits, prolonging their residence time in the water column.

Keywords: MP settling velocity, MP settling trajectory, Wave effect.

CFD MODELING OF WAVE-INDUCED FORCES ON A BERM BREAKWATER CROWN WALL

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Abstract

There are several approaches in the literature for design of crown walls. Pedersen (1996) is arguably the most common design formula that is also included in many design guidelines including Coastal Engineering Manual and the Rock Manual. Norgaard et al. (2013) showed that Pedersen formula overestimates waves forces in shallow water and modified the design approach based on new experimental measurements. These widely used experimental studies are conducted on single-sloped mound breakwaters and do not cover berm breakwaters. In the literature, the only study on crown walls on top of a berm breakwater was presented by Torum et al. (2012). Their findings indicate that, in the case of reshaping berm breakwaters, the measured wave pressures and wave-induced forces are lower than those calculated using the Pedersen formula. In this study, comprehensive computational fluid dynamics (CFD) simulations have been carried out using a porous-media flow solver, *ibmPorFoam*, developed by Guler (2020) in OpenFOAM environment. The effect of turbulence is addressed using the stabilized k-ω model (Larsen and Fuhrman, 2018). The model is validated based on the experiments presented by Torum et al. (2012). Snapshots from the CFD simulations indicating the turbulent kinetic energy levels and related instant pressure distribution are given in Figure 1a and Figure 1b respectively. Then, further studies are conducted on various hardly reshaping berm breakwater cross-sections using the validated CFD model, changing the berm widths and berm elevations as well as protected and unprotected parts of the crown walls. To optimize the computational time, a focusing wave group is generated using new wave theory (Tromans et al., 1991), and this wave group is used to represent wave action of highest wave in a random irregular wave series instead of directly implementing irregular wave series. The computed wave pressures around the crown wall are integrated and the resulting forces are compared with Pedersen (1996) and Norgaard et al. (2013) formulations. Finally, a new design approach for the crown walls on top of hardly-reshaping berm breakwaters are proposed.

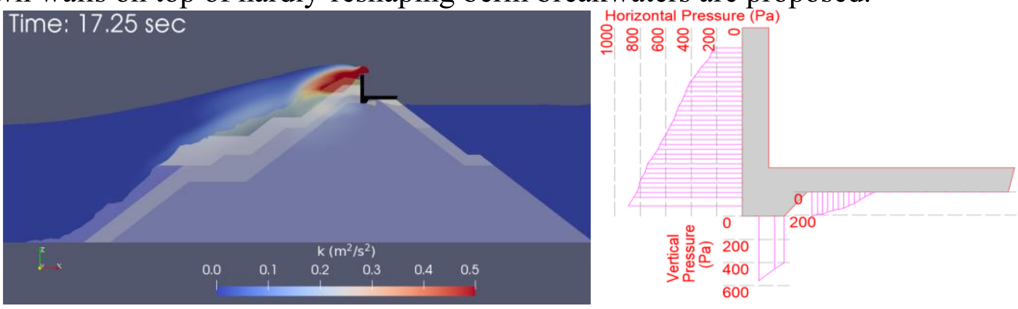

Figure 1. Snapshots from the CFD simulations indicating **a)** the turbulent kinetic energy levels at 17.25s and **b)** instant Pressure Distribution

Keywords: OpenFOAM, Crown Wall, Berm Breakwater, Hardly-reshaping