DMPCO 2023

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DESIGN AND MANAGEMENT OF PORT, COASTAL AND OFFSHORE WORKS

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GEOTECHNICAL & GEO-ENVIRONMENTAL ENGINEERING

PREFACE

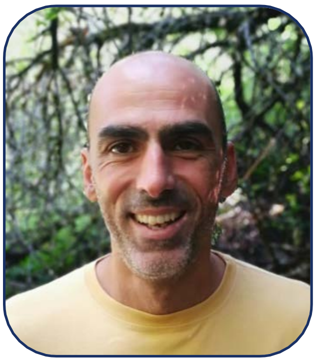
Ports, coastal and offshore structures play a strategic role for the socio-economic development of citizens in Europe and worldwide, facilitating the sustainable and secure implementation of various human activities, such as transportation, fishing, leisure and aquaculture, the protection of coastal areas and the exploitation of energy sources in the marine environment. Contemporary societal needs, including mitigation of climate change impacts, protection against coastal flooding and extreme events, clean, affordable and secure energy, security of supplies and decarbonisation of marine facilities, have redefined, nowadays, the significance of all coastal and offshore infrastructures, and have introduced new technological challenges in the whole life-cycle of those structures. Still, a great potential for innovation and growth has been emerged taking advantage of the numerous opportunities that seas and oceans provide.

The **2nd International Conference on Design, Management of Port, Coastal and Offshore Works** (DMPCO 2023) aims to stimulate comprehensive discussions and scientific interactions among the participants about the new trends and the state-of-the-art developments in the design and management of ports, coastal and offshore structures. As a sequence of DMPCO 2019, the Conference provides a forum for presenting new ideas and enhancing scientific and applied knowledge for engineers and scientists working in the relevant fields.

DMPCO 2023 has successfully attracted the interest of 221 authors from Greece, Cyprus, United Kingdom, Belgium, Netherlands, Romania and Georgia. The submitted papers have been allocated into 14 sessions. The “Coastal Modelling” session is organized in the honour of Professor Emeritus Christofer Koutitas and the “Offshore Renewable Energy I” session is dedicated to the memory of Professor Emeritus Demos Angelides. Finally, 5 keynote speakers will present cutting-edge topics.

We would like to thank all authors and keynote speakers for their contributions and we really hope that all participants will enjoy the Conference.

Professor Theofanis Karambas
Associate Professor Eva Loukogeorgaki
Chairs of the Organizing Committee



Dr. **Michalis I. Vousdoukas** is a coastal oceanographer, currently employed as Assistant Professor in the Department of Marine Sciences of the University of the Aegean. He graduated at the Chemical Engineering Department of Aristotle University of Thessaloniki, Greece (2002). After being awarded his PhD on coastal morphodynamics (2006) he has worked at the NATO Underwater Research Center (Italy), IFREMER (France), University of Algarve (Portugal), University of Hannover (Germany), and the European Commission's Joint Research Centre (JRC). Since 2015, he is appointed Associate Professor in the Department of Marine Sciences of the University of the Aegean. He has been involved in several European and national research projects, dealing with monitoring and modelling of nearshore morphodynamic processes. Since 2013, he is developing tools and methodologies allowing to assess climate change impacts along the European and global coastlines. These efforts cover the whole spectrum from hazard, to impact and adaptation, including large-scale ocean modelling, exposure datasets and risk assessment. He is author of more than 70 scientific journal papers, of 2 book chapters and of several international policy and technical reports. He regularly acts as invited expert for the United Nations Conference on Trade and Development (UNCTAD) in activities supporting climate change adaptation and sustainability. He also acted as Contributing Author to the IPCC Working Group I Sixth Assessment Report: Chapter 12 (Climate change information for regional impact and for risk assessment), and as lead author to the 1st MedECC Assessment Report (MAR1).

Dr. **Vasilios Kapsimalis** is Research Director of the Department of Marine Geology and Geophysics of the Institute of Oceanography, Hellenic Centre for Marine Research (HCMR). His research interests are in marine sedimentology and geomorphology, coastal resilience, marine geochemistry and pollution, underwater geoarchaeology, Late Quaternary and Holocene stratigraphy, and relative sea level changes. He has published more than 50 papers in peer-reviewed journals, and presented more than 80 original contributions in international and Greek conferences. In addition, he has coordinated more than 50 research projects dealing with marine pollution, sediment quality assessment, dredged material management, coastal erosion, underwater geoarchaeology and stratigraphy of continental shelves. He has organized and participated, as Party Chief, in numerous marine geological and geophysical surveys using the HCMR's fleet. His educational work is related to the teaching of graduate and postgraduate courses at the Harokopio University of Athens, the National Technical University and the Aristotle University of Thessaloniki, and the supervision of forty-three BSc, MSc and PhD theses. Since 2022, he is the Deputy Director of the Institute of Oceanography and the representative of HCMR at the Hellenic Foundation for Research and Innovation.

Professor **Peter Troch** holds an MSc and PhD degree in Civil Engineering from Ghent University. He has 30 years of academic experience in the field of coastal engineering and integrated water management. His research focuses on coastal structures (wave run-up and wave overtopping, pore pressure propagation in porous structures, scour protection), wave propagation modelling, wave energy converters (modelling of wake effects) and eco-hydraulics (vegetated lowland rivers, tidal marshes). For his research, he is developing and using experimental and numerical modelling tools and field monitoring. He has been member and coordinator for a large number of national and international research projects, supervisor of 20 finished PhD research topics and leads a research group of currently 10 PhD students and 5 post-docs. He has published more than 120 peer reviewed journal papers, 330 conference papers and numerous technical reports, and he is co-author of the international EurOtop overtopping manual. Prof. Troch is member of various scientific committees of conferences in his fields of research, and he has organized the CoastLab12 Conference in Ghent. He has been Coastal and Maritime Hydraulics Committee Officer of IAHR, member of the Board of Directors of PIANC Belgium, and member of various international commissions of PIANC worldwide. He is associated editor of the Elsevier journal Coastal Engineering, and reviewer of many scientific journals and international research agencies. He has been an expert advisor for a range of (inter-)national coastal engineering projects. Currently, he is the Department Chair and the Director of the Coastal Engineering Laboratory at UGent, and he is coordinating the design and construction of the new wave basin at Ostend Science Park (Belgium).

Panagiotis Prinos, Professor of Hydraulic Engineering in the Civil Engineering Department of the Aristotle University of Thessaloniki (AUTh), Greece, received his Diploma of Civil Engineering from the University of Patras (Greece), his MSc in Hydraulics, Hydrology and Coastal Dynamics from Strathclyde University (UK), and his PhD from the University of Ottawa (Canada) in 1984. He joined the AUTh Civil Engineering Department as an Assistant Professor in 1992 and he became full Professor in 2000. He has served as Chair of the AUTh Civil Engineering Department, as Director of the Hydraulics and Environmental Engineering Division of the Department, while since 2010 he is the Director of the Hydraulics Laboratory. In 2003, he was the co-chairman of the LOC of the XXX IAHR Congress in Thessaloniki. He has been the coordinator of the Hellenic Network on Coastal Research (HeNCoRe) of the respective European action ENCORA and a member of several national and international Associations (e.g. IAHR, New York Academy of Sciences). He has reviewed many papers in several international journals. He has served as a chairman of the Maritime Hydraulics Section of IAHR (2005-2007) and he has been member of the IAHR council (2007-2011). He has published over 50 papers in international journals and over 150 in international and national conferences. Apart from his research interests in basic fluid mechanics and hydraulics research (turbulence, open channel flow etc.) he has been active in applied maritime hydraulics and coastal engineering research by participating in several national and European projects.

Prof. **Maurizio Brocchini** is an expert in the hydrodynamics and morphodynamics of coastal, estuarine and riverine waters, with over 30 years of experience in the field. His main area of research is the mathematical and numerical modelling of shallow water and turbulent flows. He graduated in Theoretical Physics, with full marks and honours, in 1989 at the University of Bologna (Italy). He awarded his PhD in Applied Mathematics in 1996 at the University of Bristol (UK). Formerly Head of the Civil, Building Engineering and Architecture Department at the Università Politecnica delle Marche, Ancona, he is Full Professor of Hydraulics and Fluid Mechanics. He was tutor for 18 PhD theses and for over 50 MSc theses. He is author/co-author of around 150 peer-reviewed papers appearing on Scopus/ISI-listed international journals, with total citations of over 3700 and h-index of 33 (Scopus). He was awarded by the European Community a Marie Curie Fellowship for research in the years 1993-1996. Listed among the "World's Top 2% Scientists".

DMPCO 2023

EXTENDED ABSTRACTS

Modelling Earthquake-Generated Tsunamis: Considerations on the Effects of Fault Models on Tsunami Generation and Propagation

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INTRODUCTION

This work investigates the effect that earthquake fault model types and properties have on the numerical modelling of tsunami generation and propagation. This is done using a 2DH post-Boussinesq model (Samaras and Karambas, 2021), properly adapted to represent tsunami waves generated by dynamic bed deformations due to dip-slip faulting.

THE 2DH POST-BOUSSINESQ MODEL

The model's momentum and continuity equations are written as follows:

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}+g\frac{\partial \zeta}{\partial x}= -\int_{\infty}^{\infty}\int_{-\infty}^{\infty}\left(\frac{\partial \zeta}{\partial x}(x-\xi_1,x-\xi_2,t)-\frac{\partial \zeta}{\partial x}\right)K(\xi_1,\xi_2)\,d\xi_1 d\xi_2 \quad (1)$$

$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}+g\frac{\partial \zeta}{\partial y}= -\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\left(\frac{\partial \zeta}{\partial y}(x-\xi_1,x-\xi_2,t)-\frac{\partial \zeta}{\partial y}\right)K(\xi_1,\xi_2)\,d\xi_1 d\xi_2 \quad (2)$$

$$\frac{\partial \zeta}{\partial t}+\frac{\partial\left[(d+\zeta)U\right]}{\partial x}+\frac{\partial\left[(d+\zeta)V\right]}{\partial y}=0 \quad (3)$$

where *U*, *V* are the depth-averaged velocity components along the x- and y- directions, respectively, ζ is the free surface elevation, *d* is the water depth and the kernel *K(x,y)* is given by Eq. (4), in which $r^2=x^2+y^2$. Further details on the model can be found in Samaras and Karambas (2021).

$$K(x,y)=\frac{g}{2\pi d^2}\left[\frac{1}{r/d}-\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{\sqrt{n^2+(r/d)^2/4}}\right] \quad (4)$$

BED DEFORMATIONS & MODEL ADAPTATION

In the case of a finite rectangular fault of width *W* and length *L*, positioned at a depth d_f below the free surface, exponential bed deformation is expressed as:

$$\zeta_b(x,y,t)=O(x,y)\left(1-e^{-\kappa t}\right) \quad (5)$$

where *O(x,y)* is the vertical displacement field according to Okada (1992) and κ is a coefficient for the description of the exponential motion. The post-Boussinesq model is adapted to represent the active generation of tsunami waves, through additional terms (including ζ_b) in the momentum and continuity equations.

Regarding the vertical deformation component, it is noted that the formula proposed by Okada (1992) represents a homogeneous fault model; for heterogeneous fault models the composite deformation field is derived by first applying the formula to each of the sub-faults and then merging all sub-faults' contributions.

MODEL APPLICATIONS

Based on the previous, it is deduced that fault models of different intrinsic properties (i.e. strike/dip/rake angles, size, depth), as well as fault models of different type for the same earthquake (i.e. homogeneous vs heterogeneous) lead to significantly different bed deformation fields and, consequently, tsunami waves of different characteristics. Runs of the post-Boussinesq model for various fault model configurations and results for the case study of the May 2nd, 2020 earthquake south of Crete (Triantafyllou et al., 2023) are analysed and discussed in order to provide insights regarding the modelling of earthquake-generated tsunamis.

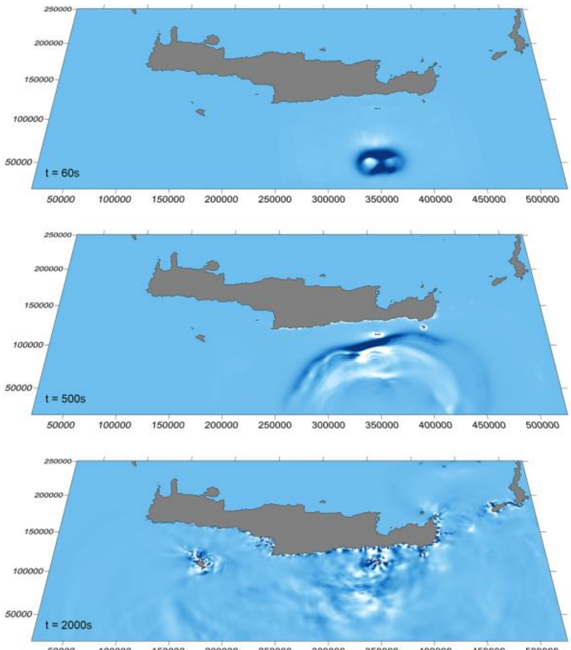

Figure 1. Model results for the May 2nd, 2020 earthquake-generated tsunami south of Crete (adopted from Triantafyllou et al. 2023).

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Quasi-Coherent Spectral Wave Modelling

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THEME OF RESEARCH

This study presents results obtained in the process of reproducing and cross validating the findings of the Quasi-Coherent (QC) spectral wave modelling approach (Smit et al., 2013). It is part of a PhD research, which aims to further validate the underlying theory, examine the behavior of a numerical spectral wave model, that was developed based on the QC theory and explore additional use cases, where this modelling framework may prove more beneficial, than the one of the classic spectral, phase-averaged wave models. In the present study, we aim to offer additional insight into the numerical implementation of the QC theory.

METHODOLOGY (DATA & MODEL)

A numerical spectral wave model was built from the ground up, to perform simulations using the QC modelling approach. The core of the model is consisted by the governing equation:

$$\partial_t W + c_k \nabla_k W + c_x \nabla_x W = S_{qc} \quad (1)$$

where,

$$c_k = -\nabla_x \sigma, c_x = \nabla_k \sigma \quad (2)$$

$$\sigma = \sqrt{gktanh(kh)} \quad (3)$$

$$S_{qc} = -i \sum_q \Delta\hat{\Omega}^q (k, x, -i\nabla_x) W \left(k - \frac{q}{2}, x, t\right) + C.C. \quad (4)$$

$$\Delta\hat{\Omega}^q (k, x, -i\nabla_x) = \Delta\hat{\sigma}^q - \frac{i}{2} \partial_k (\Delta\hat{\sigma}^q) \tilde{k} \vec{\nabla}_x \quad (5)$$

$\Delta\hat{\sigma}^q$ represents the Fourier transform $\Delta\hat{\sigma}^q = \overline{F}_{\xi,q}\{\Delta\sigma\}$

Δσ is the difference between the local dispersion function value and its local plane approximation, multiplied by a Tukey Window Function, which approaches zero as |ξ| approaches its maximum selected value:

$$\Delta\sigma = TWF(\xi)\left[\sigma(k, x + \xi) - \sigma(k, x) - \xi \nabla_x \sigma|_{k,x}\right] \quad (6)$$

It should be noted that W(k,x,t), which is being transported by Eq. (1), is not the regular wave variance density spectrum, but a more general Coupled Mode spectrum, that is essentially a Wigner-Ville distribution. The CM spectrum may reduce to the variance density spectrum, where the wave field is quasi-homogeneous. It includes the complete second-order statistics of the wave field, accounting for its coherence and more accurate stochastic representation of wave interference. When S_{qc} is absent from Eq. (1), the governing equation reduces to the radiative transfer equation, which is the backbone of modern spectral wave models, and W to the variance density spectrum. The resulting model was used for simulating Test Cases from the well-known experiments presented in Vincent et al. 1989. These include both the cases that correspond to the simulations conducted by Smit et al.,2013, as well as additional ones. Two distinct simulations were carried out for each Test Case, one with S_{qc} activated and the other with the reduced radiative transfer equation.

RESULTS

Results show that the model with S_{qc} activated was able to approximate the higher significant wave height values detected behind the shoal, as opposed to the 'regular' spectral wave model formulation. The modelled values are close to the observational data. Moreover, the QC modelling approach seems to be able to reproduce the wave interference patterns in the wave field, that the classic model fails to resolve. Local undershoots may appear when simulating the propagation of very narrow incident spectra. However, this can be ameliorated by adjusting the smoothing effect of TWF in S_{qc} in combination with appropriate finite difference schemes.

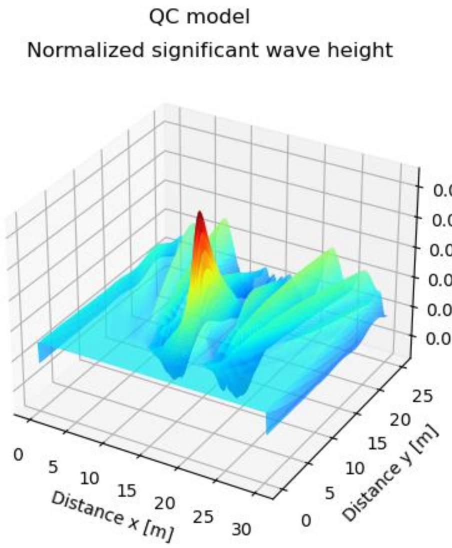

Figure 1. 3d surface of normalized significant wave height. QC model results for Test Case M2, Vincent et al., 1989.

CONCLUSIONS

The results show that our model can reproduce the findings predicted by the QC modelling framework. Slight differences with the results of Smit et al., 2013 are detected. These are attributed to the differences that almost certainly exist between the two overall solution algorithms, bearing in mind that our model was built from the ground up and Smit et al., 2013 mention only very basic aspects of their numerical implementation and model parameterization. The careful selection of TWF formulation and numerical schemes may prevent undershoots without sacrificing accuracy.

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CoastFLOOD: Fine-Resolution Modelling of Flood Inundation due to Storm Surges in the Coastal Zone

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THEME OF RESEARCH

Storm surges due to severe weather events threaten low-land littoral areas by increasing the risk of seawater inundation of coastal floodplains. The latter is mainly responsible for land loss, coastal erosion, damages on onshore infrastructure and properties, environmental degradation of coastal aquatic ecosystems, saltwater intrusion in coastal aquifers, and occasionally human casualties, etc. In this paper, we present recent developments of a numerical modelling system for coastal inundation induced by sea level elevation due to storm surges, potentially enhanced by astronomical tides and/or Mean Sea Level (MSL) rise.

METHODS AND DATA

CoastFLOOD is a reduced complexity numerical model for high-resolution simulations of coastal inundation in local-scale littoral floodplains. It is fed either by outputs of regional-scale simulations of storm surges (Sea Surface Height, SSH) with MeCSS or HiReSS models (for climatic projections or operational forecasts, respectively; Androulidakis et al., 2015) or field data for Sea Level Anomaly (SLA) by satellite altimetry and *in situ* observations at the coastal zone (Androulidakis et al., 2022). CoastFLOOD performs highly detailed modelling (on a dx=2-5m resolution ortho-regular Cartesian raster grid) of seawater uprush and flood routing due to episodic, mid- or long-term, sea level elevation on the coastline. The latter is induced by storm surge events, further enhanced by tidal effects and MSL rise due to climate change. Thus, CoastFLOOD is a fine-resolution, 2-D horizontal, GIS raster-based storage-cell, mass balance flood model for low-land coastal areas, following the concept of a simplified form for the Shallow Water Equations (SWEs) similar to the established LISFLOOD-FP model (Bates et al., 2010). The storm surge on the shoreline drives the seawater flow on the coastal floodplain via Manning-type equations in decoupled 2-D formulation (Skoulikaris et al., 2021). New updated features of the model are discussed herein concerning the detailed surveying of terrain roughness and bottom friction, expansion of Dirichlet boundary conditions for coastal currents (besides sea level), enhancement of wet/dry cell techniques for flood front propagation over steep water slopes, etc. Furthermore, several issues are discussed about the proper inclusion of coastal structures, port infrastructure, beach formations, and rocky shores in the model grid. Land elevation grids are derived by post-processing of available geospatial datasets from the Digital Elevation Model (DEM) of Hellenic Cadastre (https://www.ktimatologio.gr/en) available in 4600×3600 m^2 ground plates on a GGRS87 projection. The operational forecast model validation is performed with the use of satellite observations (Sentinel-2 images) producing the Normalized Difference Water Index (NDWI).

SIMULATION RESULTS & MODEL VALIDATION

The modelling system is applied to the littoral floodplains of several selected sites along the Greek coastline, covering the continental and insular seaside of the Aegean and Ionian Seas. CoastFLOOD results are also compared to simplified, static level, "bathtub" inundation approaches with or without hydraulic connectivity. Examples of simulated results and integrated satellite estimations of "wet" flooded areas are provided in Figure 1.

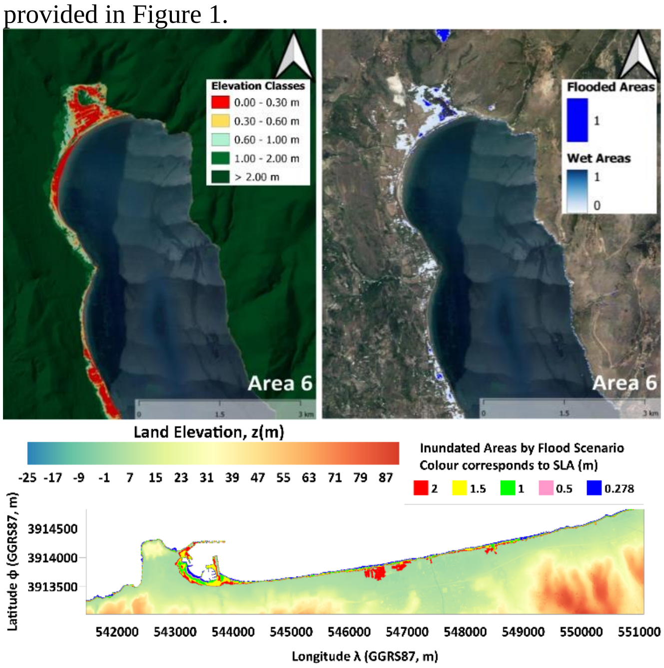

Figure 1. Maps of classified land elevation (DEM; upper left), Flooded and Wet Areas derived from the NDWI difference between 15-20/9 (upper right) for Livadi bay in Cephalonia Island (storm surge due to IANOS). Coastal inundation hazard map in Rethymno city (in northern Crete) for 5 different scenarios of SLA=0.273, 0.5, 1.0, 1.5, 2.0 m (lower map).

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Impact of Sea Level Variability on Coastal Inundation in the Aegean, Ionian and Cretan Seas

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THEME OF RESEARCH

Sea level is a key element of global scale climatic changes with potentially significant coastal impacts especially on the low-lying areas of the Mediterranean Sea, which is one of the most vulnerable regions to sea level rise worldwide. The sea level variability controls the inundation levels of the coastal zone, depending on the local topographic characteristics and the occurrence of severe meteorological events (e.g. storm surges). The scope of the study is to evaluate the interannual and spatial variability of the Sea Level Anomaly (SLA) over the Aegean, Ionian and Cretan (AIC) Seas and evaluate the impact on the coastal inundation characteristics along the topographically complex Greek coastline from 1993 to 2021.

METHODOLOGY

The satellite altimetry SLA data (sea surface height above sea level), covering a 29-year period (1993-2021), has been collected from the Copernicus Marine Service to investigate the sea level variability over the AIC region and provide the boundary conditions of the coastal flooding simulations. A high-resolution (dx = 5 m) Digital Elevation Model (DEM; Hellenic Cadastre: https://www.ktimatologio.gr/en) was used to describe the low-lying coastal areas along the AIC coastline and serve as topography input in the inundation estimations and simulations. The coastal inundation over the AIC low-lying areas is simulated with the CoastFLOOD model (Makris et al., 2022), which is a depth-averaged, 2-D horizontal, mass balance, flood flow model, especially indicated for coastal areas (Androulidakis et al., 2022). It follows the concept of the 2-D floodplain version of the established LISFLOOD-FP model (Bates et al., 2010). The coastal flooding simulations cover the entire study period and derive interannual results of the inundation variability at 20 study cases along the AIC coastline. Satellite imagery from Sentinel-2 was used to compute the Normalized Difference Water Index (NDWI) and evaluate the CoastFLOOD estimations of severe flooding events during the study period.

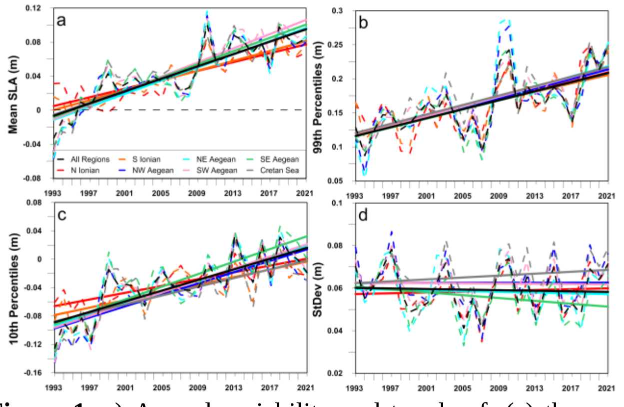

Figure 1. a) Annual variability and trends of: (a) the mean SLA; (b) the 99th percentile; (c) the 10th percentile, and (d) the standard deviation (StDev), averaged over 7 AIC regions for the period 1993–2021.

RESULTS

The interannual evolution of the mean annual SLA, averaged over 7 AIC sub-regions, revealed clear positive trends during the 1993-2021 period (Figure 1a). The general trend over the entire area was 3.6 mm/year, higher than the overall Mediterranean (2.44 mm/year; Bonaduce et al., 2016). The highest Sen's Slopes were derived for the Aegean Sea with strongest trends for the SW Aegean (4.1 mm/year). The northern Aegean revealed the highest 99th percentiles in the extreme year of 2010 (>0.25 m; Figure 1b), where the maximum SLA values of the entire study period occurred. The variability and trends of the annual SLA and the respective annual frequency of flooding at 20 selected low-lying areas of the AIC domain are presented in Figure 2. Strong positive trends of flooding annual frequency were computed in coastal regions of the northern Aegean (>8%/decade), associated to the increasing SLA levels and the low-land characteristics of these areas.

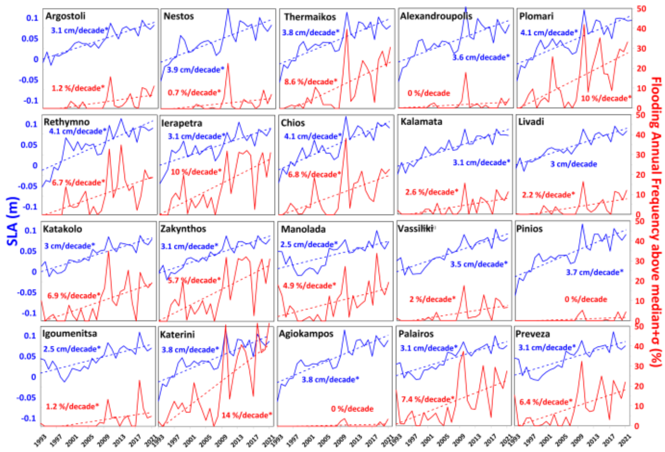

Figure 2. Annual evolution of mean SLA and annual frequency of flooding above the median+StDev threshold for 20 coastal areas during 1993-2021. The linear regressions and the respective Sen's Slopes for each case are also shown.

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Analysis of Extreme Storm Surges at the Mediterranean Coastline under Climate Change

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INTRODUCTION

Global climate change is associated with extreme marine events of higher intensity and frequency and mean sea level rise, increasing vulnerability and exposure of coastal areas to flooding and erosion phenomena. Extreme wave and surge storm events constitute the primary sources of coastal risks, rendering a reliable estimation of their extreme levels urgent, especially for future weather conditions.

Intense storm surge events threaten low-elevation coastal areas of the Mediterranean Sea with inundation risk, resulting in human casualties, severe damages to properties and infrastructure, as well as deterioration of the coastal environment. The extreme storm surge climate varies significantly among different regions of the Mediterranean coastline, especially due to the diverse topographical characteristics of its regional seas.

STUDY AREA AND CLIMATE CHANGE DATA

The surge-induced sea level (Sea Surface Height, SSH) data in coastal regions of the Mediterranean Sea result from high-resolution simulations with Mediterranean Climate Storm Surge (MeCSS) model, a 2-DH barotropic simulator of hydrodynamic ocean circulation based on the depth-averaged shallow water equations (Androulidakis et al., 2015). Simulations cover the reference (1971-2005), the short-term (2021-2055) and the long-term (2066-2100) future climate (Makris et al., 2023). The atmospheric forcing of the model consists of wind (velocity and direction) and atmospheric pressure fields by a high-resolution Regional Climate Model (RCM) by GUF (Goethe Universität Frankfurt), implemented in the framework of the MED-CORDEX initiative (https://www.medcordex.eu/; Ruti et al., 2016). The GUF-CCLM-NEMO is an atmospheric-ocean circulation ensemble model collaboration based on a finite difference, hydrostatic, primitive equation ocean general circulation model, with free sea surface and non-linear equation of state. Historical climate data for the reference period are validated against ECMWF (European Centre for Medium-Range Weather Forecasts) reanalyses, based on assimilation system fields produced under CERA-20C. Future estimations of the GUF RCM are based on two climatic scenarios of the Representative Concentration Pathways, RCP 4.5 and RCP 8.5 (IPCC, 2014). Average annual maximum SSH maps are first extracted for the entire Mediterranean coastline, for the historical data, as well as for the two future periods with both RCPs.

EXTREME VALUE ANALYSIS

Extreme value methods are powerful statistical techniques for analysing the highest values of a process and for extrapolating to levels more rare compared to any previously observed or simulated. The Generalised Extreme Value (GEV) and Generalised Pareto (GP) distributions fitted to maximum values in a block (of length usually equal to one year), or to peaks exceeding an appropriately defined threshold (POTs), are most commonly used for estimating extreme storm surges.

In this work the GEV distribution function is fitted to annual maximum storm surge events of all three 35-year periods (Reference and two Future Periods) for all the littoral grid cells of the GUF-forced MeCSS model along the entire Mediterranean coastline. Extrapolated storm surge return levels (Sea Surface Height extreme, SSH_{ext}) corresponding to return periods of 50 and 100 years are then extracted and intercompared among the different areas of the Mediterranean Sea (Figure 1). Stationarity and independence of the 35-years annual maxima for both the historical and future climate conditions are checked using the Mann-Kendall trend and the Wald-Wolfowitz tests (Galiatsatou et al., 2019).

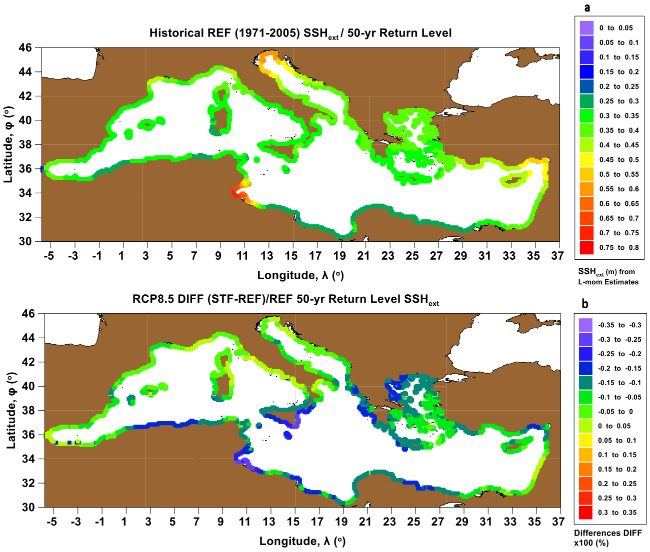

Figure 1. a) Mediterranean coastline maps of historical 35-year SSH_{ext} (1971-2005) of 50-year return level; b) difference percentage of SSH_{ext} (×100%) between RCP8.5 long-term Future (2066-2100) and Reference Period (1971-2005) for a 50-year return period from GUF-forced MeCSS model output.

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Post-Boussinesq Modelling of Nonlinear Irregular Waves in Port Basins with Wave-Structure Interaction

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INTRODUCTION

The propagation of non-linear dispersive waves in shallow waters is traditionally numerically modelled by the classic Boussinesq-type equations. During the 1990's, many researchers within the coastal engineering/science community have produced new versions of Boussinesq-type models. These endeavors mainly account for fundamental improvements of dispersive properties for wave frequency and addition of wave breaking dissipation mechanisms (surface roller and eddy viscosity models).

SCIENTIFIC BACKGROUND

Karambas and Memos (2009) have presented a prototype version of a post-Boussinesq type wave model with a system of 2-DH equations for fully dispersive and weakly nonlinear irregular waves over any finite water depth. The model in its two-dimensional formulation, involves in total five terms in each momentum equation, including the classical shallow water terms and only one frequency dispersion term. The latter is expressed through convolution integrals, which are estimated using appropriate impulse functions.

SCOPE OF RESEARCH

In this work, an updated version of the aforementioned model is introduced. It is implemented for wave propagation and transformation (due to shoaling, refraction, diffraction, bottom friction, wave breaking, runup, wave-structure interaction, etc.) in nearshore zones and inside ports. One of the main goals is the model's thorough validation, thus it is tested against experimental data of wave transmission over and through breakwaters, uni- and multi-directional spectral wave transformation over complex bathymetries and diffraction through a breakwater gap. Case studies of model application over realistic variable bathymetries at characteristic Greek ports are also presented.

NEW FEATURES OF NUMERICAL MODEL

The new model version incorporates wave generation from any central or lateral open boundary by source term addition able to simulate both uni- and multi-directional irregular waves for several angles and directions, avoiding unphysical diffraction in the case of oblique incident waves. An enhanced methodology for peripheral sponge layers is also introduced to minimize irrational wave reflection. Moreover, by extending the model of Karambas (2003), the present wave model is coupled with a porous flow module. The 'dry bed' boundary condition is used to simulate wave runup and overtopping of subaerial breakwaters. In this way, the wave reflection from and transmission through and over the breakwater is simulated. To avoid an exceptionally fine resolution of the model domain (very small spatial discretization step), we propose the following approach. Instead of a (rubble-mound) breakwater, we consider an equivalent idealized vertically faced homogeneous porous structure with a dissipative area (by a numerical friction treatment) in its upsteram side. The flow resistance within the structure is simulated by introducing an additional term in the momentum equation given by the Dupuit-Forchheimer formula. Energy loss on the upstream side of the ideal structure (i.e., rough slope of the actual breakwater) is represented by an appropriate (numerical) friction coefficient. In this way, we can obtain the desired pre-estimated values of the reflection and transmission coefficients.

MODEL VALIDATION AND APPLICATION

Evaluation of the model's performance is conducted by comparisons of simulation results with experimental data (Figure 1) of regular and irregular wave propagation through breakwater gaps (Yu et al., 2000). Validation of model results against experimental data is satisfactory.

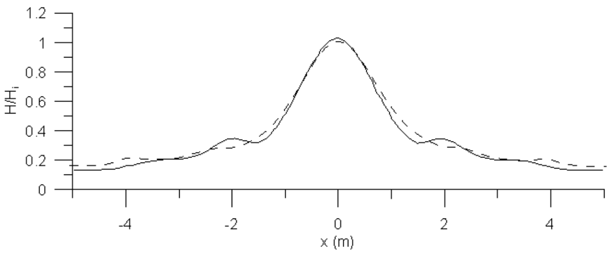

Figure 1. Comparisons of wave diffraction coefficient $K_D=H/H_i$ through a breakwater gap (solid line: experimental data, dashed line: model output).

Figure 2 presents plotted results of wave transmission with and without overtopping.

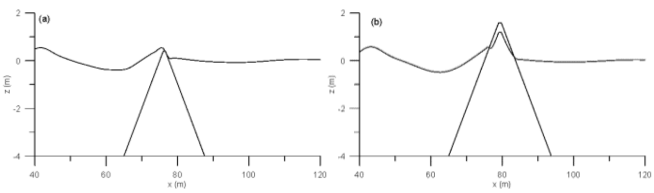

Figure 2. Wave transmission over (left) and through (right) a breakwater (a) with and (b) without overtopping.

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Assessing the Wind Wave Climate at Several Scales in the Offshore and Coastal Zones

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INTRODUCTION

Surface waves are typically a subject of coastal engineering studies, and less commonly oceanographic ones. However, surface waves significantly contribute to air-sea interaction processes, which include momentum, heat and mass exchange between the ocean and the atmosphere. In the last decades, the need to replace fossil fuels has increased the interest of the scientific community to wind-forced surface waves. This work is a contribution to the assessment of the wind-forced surface wave climate in the Aegean and Ionian Seas, with emphasis on three semi-enclosed basins, the Gulfs of Gera and Kalloni at Lesvos Island, and the Gulf of Moudros at Lemnos Island.

MATERIALS & METHODS

Wave characteristics (significant wave height, peak wave length, peak period, mean wave direction and peak wave direction) are simulated for the period 2021-2022 using Simulating Waves Near Shore (SWAN) model (Booij et al., 1999), through a three-level offline one-way nesting procedure. The first-level simulation involves a coarse (3 km resolution) grid that covers the Greek Seas (Aegean and Ionian region – Fig. 1), providing boundary conditions for the high resolution grids of Lesvos (480 m) and Lemnos (220 m) islands. The latter domains constitute the second level of nesting procedure, providing boundary conditions for the ultra-high-resolution grids (3rd level) of Gera (74 m), Kalloni (120 m) and Moudros (100 m) Gulfs respectively. For the level-1 simulations, boundary conditions are provided by Copernicus Marine Service Mediterranean Monitoring Forecasting Center (CMEMS MED-MFC) wave reanalysis (Ravdas et al., 2018), while European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 atmospheric data set (Hersbach et al., 2018) provides the wind forcing. For the level 2 and 3 models, a version of SKIRON data down-scaled to 4-km resolution (Kallos et al., 1997) was chosen as wind forcing.

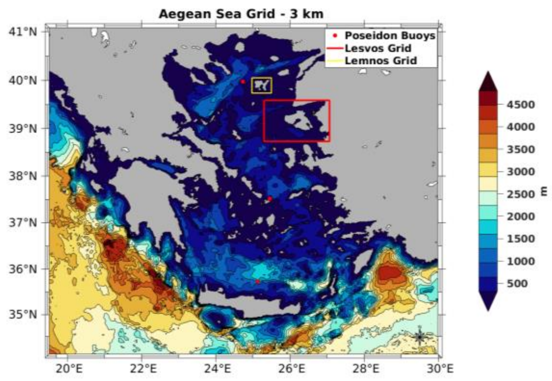

Figure 1. Aegean Sea wave model grid, along with Lesvos grid (red line), Lemnos grid (yellow line) and POSEIDON System Buoys Locations (red dots).

RESULTS

Level-1 model results have been validated using *in-situ* data from POSEIDON moorings (Athos, Mykonos and Heraklion – Fig. 2) (Ntoumas et al., 2022) while Lesvos and Lemnos results have been validated using L3 satellite observations from CMEM (Altika, CFO, Sentinel3B, H2B, *etc*). Additionally, Kalloni wave-model results are compared to *in-situ* measurements from a moored ADCP.

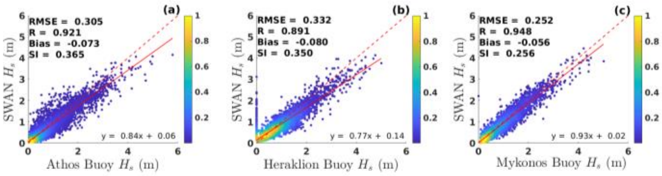

Figure 2. Scatter plot comparison of Aegean Sea significant wave height results with POSEIDON buoys at (a) Athos, (b) Heraklion and (c) Mykonos locations.

ACKNOWLEDGMENTS

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Modeling-based Results for Waves Propagations in the Case of Climate Change Adaptation Measures Assortment with Specific Reference to the Maritime Port of Constanta

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THEME OF RESEARCH

The occurrence and intensification in recent years of extreme meteorological phenomena related to climate variability/change, with strong impact on the marine environment, require a proper assessment of the risks to which port structures as and port operations are or may be endangered to certain marine hazards.

METHODS AND DATA

Considering the new expansions of Constanta Maritime Port and its specificity of design, the risk categories specific to port infrastructure projects were evaluated in relation to their exposure to the adverse effects of the wave's climate in port basin and in adjacent areas, including the way in which they could be affected.

In this regard, data were collected in relation with the location conditions, climatic variables and related hazards with medium to high sensitivity. The evaluation of the future exposure is done for the project components classified as having sensitive points or medium to high exposure, for the design horizon of 50 and, respectively, 100 years. In this study, aspects of the integrated assessment will be highlighted, based on the results of numerical modeling regarding the propagation of coastal waves in the immediate vicinity of the port, in order to identify different adaptation measures, with an emphasis on structural and non-structural measures, but also on risk management in ensuring the sustainability of port investments for expansion and modernization of Constanta Port.

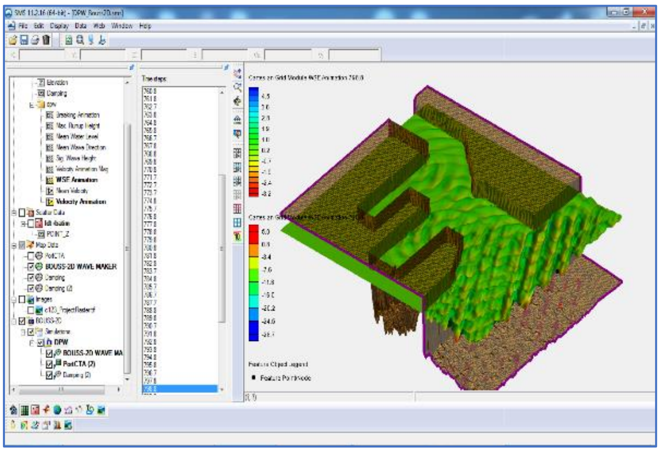

Figure 1. Wave height spatial distribution in the area of Constanta South Maritime Port, offshore direction 120°N – for a return period of 100 years.

Beyond several numerical hydrodynamic models were deemed as appropriate for the study of the wave's dynamics around Constanta Port, broadly speaking, our approach in the specific research area is precisely linked to the mechanics of the fluids and with coastal ports hydrodynamics, thus we approach several potential solution against waves propagation processes in portuary waters, allowing for subsequent developments that can in turn be used as a basis for the elaboration of various services, which at present underlie the interconnected informatics systems, with specific applicability to the field of wave energy systems, safety of the maritime transport, or MSP/Maritime Spatial Planning.

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Interaction of Gravity Currents with Internal Waves in a Linearly Stratified Ambient

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INTRODUCTION

Gravity currents (GCs) are buoyancy-driven flows in which hydrostatic pressure gradients produce a primarily horizontal motion. There are many circumstances in coastal environment where GCs propagate in a stable stratified ambient. This propagation is related with the occurrence of internal waves (IWs), as in the offshore river plume fronts which propagate as GCs generating IWs (Nash & Moum, 2005) or the onshore GCs that can be created from tidal bores (Haney et al., 2021). This study presents a new set of numerical results of bottom GC propagation in a linearly stratified environment using Large Eddy Simulation (LES). To date, the research on the dynamics of GCs in stratified environment has been focused on the constant-velocity phase (Dai et al., 2021), while this study investigates the effect of stratification strength on GC velocity throughout the phase sequence of its motion.

SETUP AND NUMERICAL MODEL

Numerical experiments are conducted in a lock-exchange configuration composed of a lock of dense fluid (ρ_c) at the left corner of a horizontal tank. The rest of the domain is covered by a linearly stratified fluid with density ρ_b at the bottom and ρ_0 at the top. The stratification strength parameter $S = (\rho_b-\rho_0) / (\rho_c-\rho_o)$ varies from 0 (weak stratification) up to 1 (strong). Froude number is defined as $Fr = U_f / NH$ where U_f is the GC front velocity, N is the buoyancy frequency and H is the tank height. Half-depth configuration is used, while the Reynolds is always equal to $2{\cdot}10^4$ considering inviscid GCs. The dynamics of propagation are different for subcritical ($Fr < 1/\pi$) and supercritical ($Fr > 1/\pi$) GCs. Numerical experiments are carried out for $0 < S < 1$ covering both the sub- and supercritical regimes. The numerical model solves the three-dimensional filtered incompressible Navier-Stokes equations. Boussinesq GCs are considered, the density is related to concentration and an extra transport equation for the concentration is used. The unresolved scales of motion are considered using a dynamic Smagorinsky SGS model. The simulations are performed using the open source OpenFOAM library.

RESULTS

Fig.1 shows the vertical velocity component of a subcritical GC ($S = 0.93$) along with the concentration isopleth. The concentration field (C) for $0.93 < C < 1$ is also shown for the GC to be distinguished. IWs are shown from the vertical velocity field from which it seems that they have outrun GC. Fig. 2 shows the GC front velocity with time. The dashed lines show the critical Fr for each S. A distinct velocity behavior is evident between the $S = 0.93$ and the rest of the experiments. For $S = 0.93$ the current is subcritical from the beginning and soon after the lock release the IW outruns the current. From that time on the GC motion is affected by the IWs (periodic curve of U_f). For $S < 0.93$, GCs are supercritical having a constant-velocity phase which is followed by a deceleration one. Deceleration continues with a decreasing rate of decrease. The GC becomes subcritical (i.e $S = 0.6$) and by the time the IW outruns it, it determines its motion similar to $S = 0.93$. Detailed results for all the examined S will be presented at the conference.

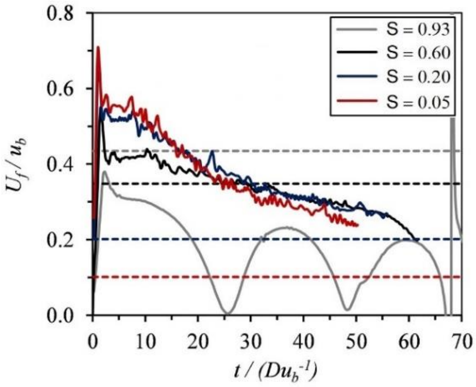

Figure 2. GC front velocity with time for all the examined S

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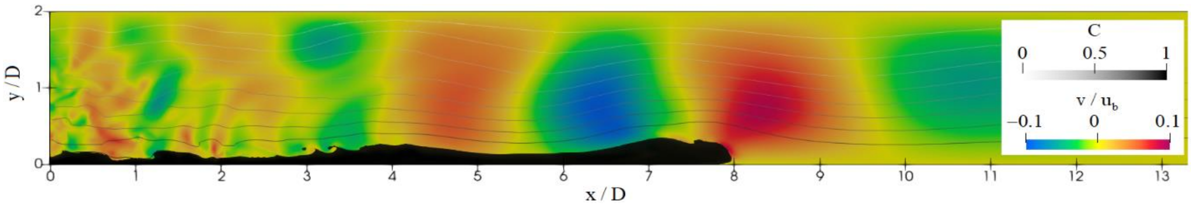

Figure 1. Vertical velocity and concentration isopleths for S=0.93 (subcritical regime)

Climate Change Effects on the Storm Surges of the Mediterranean Coastal Zone

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THEME OF RESEARCH

This study aims to systematically assess the impacts of projected climate change on episodic events of sea level elevation in coastal areas of the Mediterranean, induced by severe weather conditions identified as deep depressions. We try to add new insight in the identification of long-term, climatic timescale, impacts of low atmospheric pressure systems on the Mediterranean coastal zone correlated to storm surges during the 21st century (Makris et al., 2023).

METHODOLOGY (DATA & MODEL)

An integrated quantitative assessment is proposed by combining climatic projections from established, green-house gasses concentration scenarios (based on RCP 4.5 and 8.5) for a Reference (1971-2000) and a Future (2071-2100) Period with advanced numerical modelling and statistical post-processing for the definition of cyclonic weather impacts on characteristic coastal zone hotspots. To this end, climate projections and outputs from three Regional Climate Models (RCMs) of the Med-CORDEX initiative at the Mediterranean basin scale are used and extensively evaluated against re-analysis data. These atmospheric datasets feed a robust storm surge model (MeCSS) for the simulation of barotropic hydrodynamics (Sea Surface Height, SSH, and currents) thoroughly validated against *in situ* sea level observations by tide-gauges (Androulidakis et al., 20215).

RESULTS

Extreme storm surge magnitudes range between 0.35 and 0.50 m in the Mediterranean basin with higher values along parts of its northern coasts (Venice lagoon, Gulf of Lions, northern Adriatic and Aegean Seas, etc.) and the Gulf of Gabes in its southern part. Overall, the spatial distributions of surge maxima are estimated to remain similar to those of the past throughout the entire Mediterranean coastal zone. Differentiations between the two scenarios (RCP4.5-8.5) used are obvious, not so much related to the spatiotemporal distribution of storm surge maxima, which shows a very stable pattern, but more in terms of their magnitudes. Indicatively, a decrease of surge maxima from -30% to -2% can be observed towards the end of the 21st century, especially for RCP8.5-driven MeCSS simulations. This is a spatially averaged estimation, yet for some specific coastal sites in Croatia, Spain Italy, and France, such as Rovinj, Bakar, Toulon, Trieste, Ajaccio, Genova, Marseilles, Naples, Venice, Cagliari, Ancona, Ibixa, and Barcelona, the storm surge maxima might increase from 1% to 22% under different RCM/RCP combinations towards the end of the 21st century. The strongest correlations of deep depression events to high sea levels are observed in several parts along the northern Mediterranean coasts (Gulfs of Valencia and Lions, Ligurian and northern Adriatic Seas). They are followed by mid-latitude areas around Corsica, Sardinia, the mid-zonal Italian Peninsula and the Adriatic, and the northern Aegean Sea. The influence of deep depressions on storm surges is lower for Sicily, South Italy, Peloponnese, Crete, the southern Aegean archipelago, and Alboran Sea. The only exceptions in the generally unaffected southern Mediterranean littorals are the Gulfs of Gabes and Alexandretta. These apply to the 20th century; however, they seem to repeat for the 21st century estimations, with even more pronounced differentiations between the southern and the northern parts. A projected northward shift of the main deep depression centers over the Mediterranean towards 2100, is likely the reason for the latter. The climate change signal (difference of Future–Reference Period) of the deep cyclones' effect on the episodic increases of coastal sea level seems to have a very clear pattern of slight attenuation in certain regions, i.e., Sardinia, Corsica, the Ligurian and Adriatic Seas, and the entire Italian peninsula for all RCM-fed implementations towards the end of the 21st century (Figure 1).

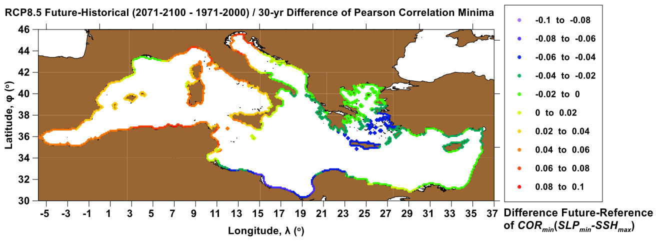

Figure 1. Spatial distribution (along the Mediterranean coastline) of the difference between the Future-Reference Periods for Pearson correlation minima of SSH_{max} to SLP_{min}.

CONCLUSIONS

Our results corroborate a projected storminess attenuation for the end of the 21st century, yet local increases in storm surge maxima around the Mediterranean coastal zone are also pinpointed. Moreover, a slight reduction of average storm-induced Mean Sea Level (MSL; component attributed solely to the meteorological residual of SSH) is also apparent towards the end of the 21st century.

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Circulation Pathways in Thermaikos Gulf based on Field and Model Lagrangian Experiments

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THEME OF RESEARCH

The Northern Thermaikos Gulf (NTG; Figure 1) is a semi-enclosed coastal region of the Aegean Sea, characterized by anthropogenic and natural stresses such as intense industrial and agricultural activities, urban outflows, and several river discharges facing severe pollution events. The hydrography and the hydrodynamic circulation patterns of NTG are revisited in this paper based on the findings of a multi-platform observational-modeling study, conducted during a recent annual cycle from June 2021 until May 2022. The main goal of the study is to investigate the environmental conditions that determine the renewal and water quality of the semi-enclosed basin.

METHODOLOGY

The monitoring period covered an annual cycle from June 2021 to May 2022 with a 2-monthly temporal step (6 campaigns). The near-surface circulation pathways investigation was based on 12 Lagrangian experiments with autonomous, satellite-tracked and free-drifting floats ("AEGEAN" drifters) for recording ocean current velocities at different times and locations during the observational campaigns. Daily discharges of rivers, canals and drainage trenches are derived by Hydrologic Modeling System (HEC-HMS) simulations of hydrologic processes at the river catchment scale affecting the NTG (Figure 1). The hydrodynamic circulation conditions during 2021-2022 were reproduced by numerical simulations with the FLOW module of the three-dimensional modeling system Delft3D-Thermaikos (Androulidakis et al., 2021). Numerical experiments of Lagrangian flows were conducted using a tracer (passive particle) model (TracerModel2D; Krestenitis et al., 2007), forced by Delft3D-Thermaikos' current fields. We examined the connectivity pathways between the river outflows and the broader NTG. Current (Acoustic Doppler Current Meter: ADCP) and physical (CTD) measurements (at 6 stations) were also collected in situ during 6 campaigns.

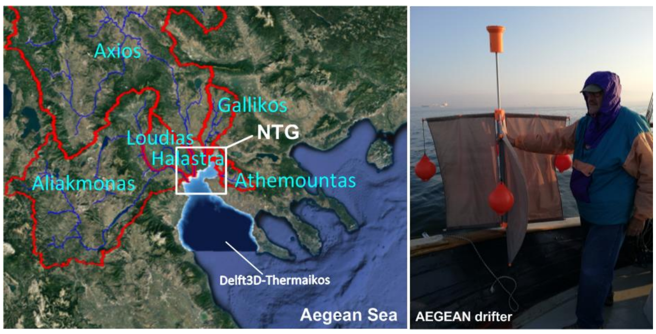

Figure 1. Location of NTG, river system, drainage basins, and Delft3D-Thermaikos model domain (left). Drifter deployment (right).

RESULTS

Numerical Lagrangian experiments were developed to cover the same periods of the drifter trajectories and the ADCP measurements (Figure 2). The spreading of the simulated particles (TracerModel2D) agrees with the surface currents derived from the ADCP measurements and the overall drifter trajectories. Field and numerical experiments reproduced the prevailing circulation conditions over the NTG during 6 study periods of the annual cycle. Monthly numerical experiments were also conducted for all the land/river stress/pollution sources (Figure 1) to investigate the seasonal connectivity pathways of freshwaters over the NTG domain.

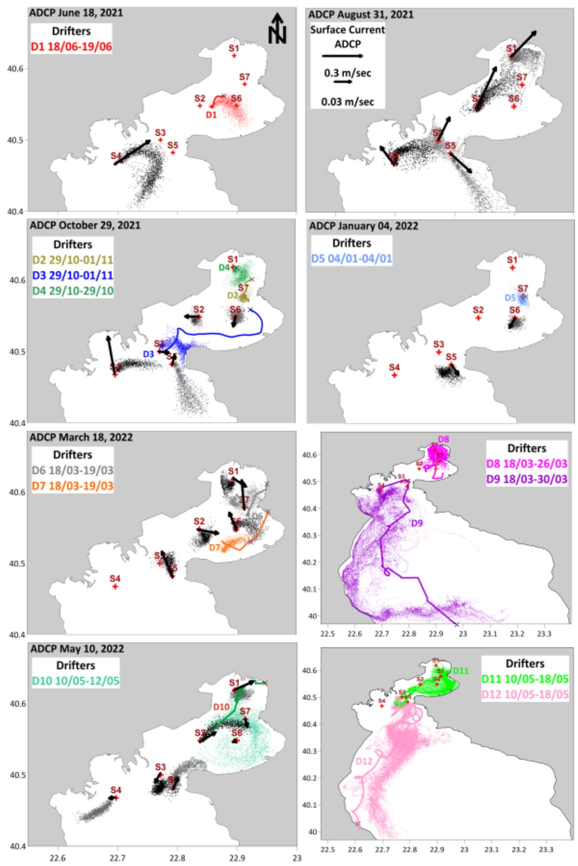

Figure 2. ADCP surface currents (vectors), trajectories of 12 drifters (lines), and positions of 100 simulated particles (for each experiment) during the same periods.

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On Using Submarine Cables to Monitor Water Transport: the Case of Intensely Baroclinic Oceanic Flows

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INTRODUCTION

The use of submarine cables to monitor water transport via the measurement of voltage difference between two opposing coasts is an established and well-documented method to measure water volume flows used for many decades now. While it was first proposed by Faraday in 1832, it was not until the 1970s that it was applied in the Florida Keys (Sanford, 1971) and has since been used in several applications and scales. In the first-ever attempt to apply this method over a very narrow strait at the entrance of Kalloni Gulf in Lesvos island, Greece (Petalas et al., 2020), the voltage recorded between the two coasts exhibited a significantly diverging spectrum than the transport estimated by either modelling or sea-level measurement and closing the water volume budget of the basin. In this work we investigate whether the intense baroclinicity of the exchange flow through the Strait could be the source of the failure of the cable method to reproduce the variability of the flow.

MATERIALS AND METHODS

The impact of baroclinic flow on the response of the voltage induced between two opposing coasts of a Strait was investigated both theoretically and numerically.

The theoretical approach was implemented by simulating the electromagnetic response of the Strait as an electrical circuit with the electromotive force alternating at tidal frequencies following the direction of the current, and focusing on the temporal response of the voltage difference induced at the two coasts. In this approach, the conductivities of the seawater and seabed are represented by the electrical resistance of parts of the circuit.

In numerically simulating the voltage difference between the two coasts, we exploit results from a numerical model of the circulation of the Gulf of Kalloni during the period of cable measurements across the Strait (19/6/2019 – 3/7/2019).

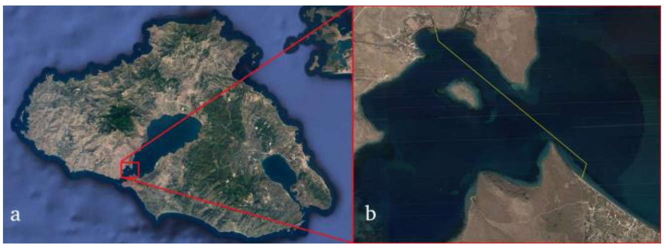

Figure 1. Left: map of Lesvos island. The red inset is enlarged and shown at the right panel, where the yellow line identifies the path of the submarine telephone cable connecting the two opposing coasts of Kalloni Strait.

The model-simulated flows have been validated based on recorded sea-level changes in the Gulf by Petalas et al. (2020). Model-obtained values of sea-water temperature and salinity have been converted to electrical conductivity, which multiplied by water velocity and integrated along the across-channel transect provide the flow of conductivity across the channel, which is proportional to the voltage difference induced across the Strait (Kim et al., 2004). The result is compared to the recorded voltage across the Strait during the same period, both in terms of temporal variability and spectral shape.

RESULTS

Both methods clearly show that intense baroclinicity does not introduce destructive noise or smoothing (figure 2). The failure of the Kalloni experiment must be attributed to poor-quality hardware or the distance of the cable's ground to the beach in connection to magnetic properties of the ground. Thus, the method is found to be applicable throughout the Hellenic marine environment.

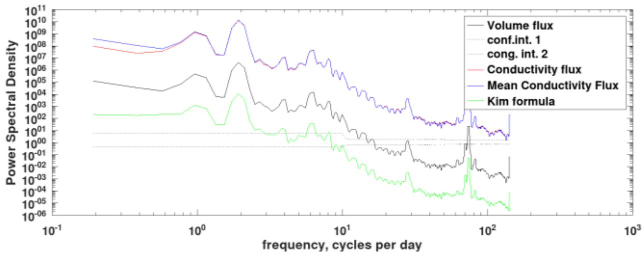

Figure 2. Comparison of volume flux spectrum with spectra of estimates proportional to the cross-shore voltage spectrum.

ACKNOWLEDGMENTS

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Optimizing the Parameterization of a High Resolution Numerical Simulation of the Saronikos Gulf Hydrodynamics

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THEME OF RESEARCH

The hydrodynamic circulation of Saronikos Gulf, an Eastern Mediterranean embayment directly impacted by Greece's capital, Athens (Fig. 1), is examined through a high-resolution implementation of the Delft3D-FLOW numerical model. The study focuses on calibrating and validating the model and on reproducing the seasonal thermohaline conditions and the prevailing circulation patterns, placing emphasis in the vicinity of inner Saronikos. As this work is carried out within the context of the EMERGE Horizon 2020 project, that develops methodologies to evaluate, control and mitigate the environmental impacts of shipping emissions, the optimized hydrodynamic model is being used to force water quality simulations to study ecosystem and pollution processes.

METHODOLOGY

The curvilinear grid developed, with resolution varying from about 1400m offshore (open boundaries), to less than 300m off Piraeus, resolves the water exchanges at the straits connecting Elefsis subbasin with Saronikos (Fig. 1). Details on model setup are given in Kolovoyiannis *et al.*, 2021.

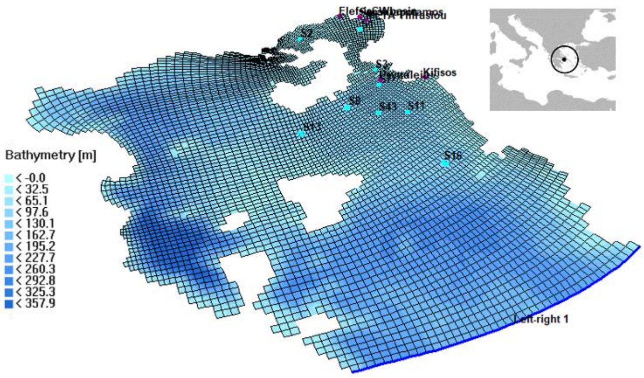

Figure 1. Saronikos Gulf computational domain, model bathymetry and HCMR sampling network.

The Nov 2009 - Oct 2010 annual cycle is simulated, forced with atmospheric data from the ERA5 database. Three sets of open boundary conditions data are used to drive the model (Mediterranean Sea Physics Reanalysis dataset by Copernicus and two implementations of the Regional Ocean Modelling System-ROMS covering the Aegean and the Eastern Mediterranean respectively), constituting three classes of numerical experiments aiming to optimize model performance. Freshwater discharges from waste treatment facilities and river flows are considered, the latter drawn from the platform Hypeweb by the Swedish Meteorological and Hydrological Institute (SMHI) after calibration with an 'inverse' approach considering simulated salinities. The effect of the number of sigma layers used to discretize the water column on model accuracy is examined: experiments with 15 and 20 layers are performed. Temperature and salinity field data collected monthly by the Hellenic Centre for Marine Research from a network of ten stations (Fig. 1), as well as satellite derived SST data are used for model validation.

RESULTS

After extensive quantitative assessment of performance (e.g. Fig. 2), analysis of results shows that the model is capable of reproducing known circulation patterns (Kontoyiannis 2010) and water column structure, constituting a valuable tool for hydrodynamic calculations and a step towards coupled marine ecosystem and pollution simulations (Fig. 3).

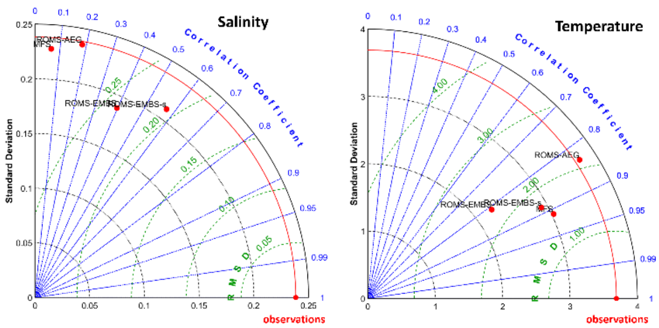

Figure 2. Evaluation of model performance under various open boundary datasets, using Taylor diagrams for salinity (left) and temperature (right).

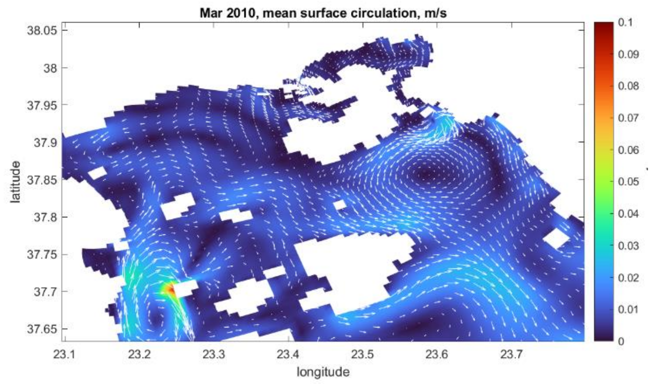

Figure 3. Simulated mean surface velocity field for March 2010 (example of model output).

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An Expanded Harmonic Separation Method to Showcase the Effects of Nonlinearity on Extreme Waves

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INTRODUCTION

This work highlights the effects of nonlinearity on extreme sea wave events that rise during directional focused wave simulations in finite water depths. For this purpose, the fully nonlinear model "HOS-Ocean" by Ducrozet et al. (2016) is considered and compared with linear simulations. Nonlinear wave harmonics were extracted combining methods by Fitzgerald et al. (2014) and Hann et al. (2014), while expanding up to the 6th order harmonic, showing the contribution of various orders of nonlinearity on the formation of extreme wave crests. The results aim to offer transparency in understanding the physics underlying such extreme events.

BACKGROUND

For the construction of nearshore and offshore structures, the prediction of the largest crest elevations of the design wave is very important for the determination of any overtopping and also the calculation of the wave loads acting on these structures. The affected area hit by an extreme event, is associated both with the crest height and width, affecting the stability and resilience of a structure or ship.

Previous work by Spiliotopoulos and Katsardi (2022) has investigated the crest shapes formed during nonlinear simulations. It was shown that "walls of water" are also formulated in finite water depth, as is the case for deep water extreme events (Adcock et. al., 2015). Indeed, the sea-state becomes more long-crested during the formulation of the extreme events in both focused and random simulations; all highly dependent on the directionality of the wavefield. The above is highlighted in the substantially increased crest width measured in the nonlinear simulations despite the decreased maximum crest elevations in intermediate water depths.

RESULTS AND CONCLUSIONS

By combining the phase separation methods of Fitzgerald et al. (2014) and Hann et al. (2014), a more detailed method for expanding up to the 6th order harmonic is derived; according to Fenton (1990) the 6th order expansion is as follows:

$$\eta(\theta) = \eta_{11}A\cos(\theta) + \eta_{20}A^2 + \eta_{22}A^2\cos(2\theta) + \eta_{31}A^3\cos(\theta) + \eta_{33}A^3\cos(3\theta) + \eta_{40}A^4 + \eta_{42}A^4\cos(2\theta) + \eta_{44}A^4\cos(4\theta) + \eta_{51}A^5\cos(\theta) + \eta_{53}A^5\cos(3\theta) + \eta_{55}A^5\cos(5\theta) + \eta_{60}A^6 + \eta_{62}A^6\cos(2\theta) + \eta_{64}A^6\cos(4\theta) + \eta_{66}A^6\cos(6\theta) + O(A^7)$$

(Eq. 1)

This harmonic separation uncovers the underlying physics behind the nonlinear evolution of extreme waves, showing the effect each harmonic has on the formation of the extreme crest (Fig. 1). The results show the pre-eminent effect of the free wave regime (whose contribution is mainly into the odd-order harmonics) into the formation of the crest shape.

This method, allows firstly to highlight that the differences that arise during nonlinear formulation of extreme events between intermediate and deep water, can be attributed to the effects of wave energy transfers which lead to an evolved underlying spectrum. Moreover, the method allows to understand which harmonics are responsible for the severe changes on the crest shape compared to linear or weakly nonlinear simulations.

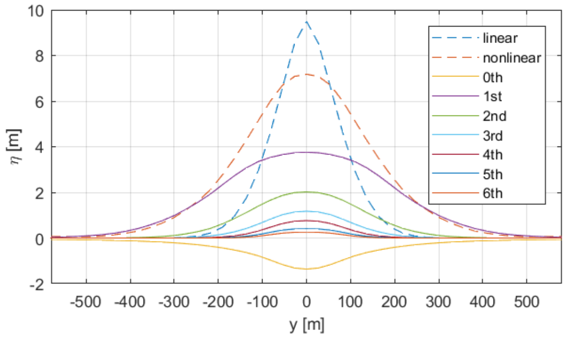

Figure 1. Nonlinear wave harmonics of an extreme wave event, y-axis cross section, highlighting crest width contributions.

In all, the ability to separate nonlinear harmonics to a higher degree, allows the better understanding of the nonlinear wave dynamics, particularly in shallower water where the effects of higher order harmonics are more pronounced. The gradual effect of each separate harmonic during changes in the effective water depth, steepness and directionality has been now made clear. These findings will work towards a better prediction of the extreme waves in any sea-state leading to a more effective design of sea structures.

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Improved Crest Height Predictions for Nonlinear and Breaking Waves in Large Storms

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ABSTRACT

The statistical distribution of zero-crossing crest heights represents a critical design input for a wide range of engineering applications. The present paper describes the development and validation of a new crest height model, suitable for application across a broad range of water depths. The purpose of this model is two-fold: first, to describe the amplifications of the largest crest heights arising due to nonlinear interactions beyond a second-order of wave steepness, and second, to incorporate the dissipative effects of wave breaking. Although these two effects act counter to each other, there is substantial evidence to suggest departures from existing models based upon weakly nonlinear second order theory; the latter corresponding to current design practice. The proposed model has been developed based on a significant collection of experimental results and a small subset of field measurements. It incorporates effects arising at different orders of nonlinearity as well as wave breaking in a compact formulation and covers a wide range of met--ocean conditions. Importantly, the new model has been independently validated against a very extensive database of experimental and field measurements. Taken together, these include effective water depths ranging from shallow water ($k_p d \sim 0.5$) to deep water ($k_p d > 3$) and sea-state steepnesses covering mild, severe and extreme conditions. The new model is shown to provide a significant improvement in crest height predictions over existing methods. This is particularly evident in the steepest, most severe sea--states which inevitably form the basis of design calculations.

INTRODUCTION

Traditional oil & gas applications, the rapidly expanding offshore wind energy sector, and different types of marine renewable devices are all examples for which accurate crest height calculations are essential. Importantly, such applications occur in a wide variety of deep, intermediate, and shallow water depths. As such, successful crest height predictions must be achievable across the full range of effective water depths.

Recent evidence suggests that measured crest heights in severe sea-states can be either under-predicted or over-predicted by present design solutions (Karmpadakis & Swan, 2022). To address this issue, a new crest height model is developed to describe the short-term distribution of crest heights in a wide range of sea-state steepness and water depths. The new model captures higher-order nonlinear effects as well as wave breaking. It is validated against both experimental and field measurements and is shown to provide an improved description of the measured crests heights in all water depths. This is important for two reasons. First, it provides a model that can be seamlessly integrated into the design process; removing the requirement to use different models for different conditions or locations. Second, it shows that the parametrisation of the model captures the main physical processes defining the crest heights in a wide range of water depths.

RESULTS

Presently, the state-of-the-art modelling of crest heights relates to predictions accurate to a second-order of wave steepness, primarily using the model developed by Forristall (2000). While this offers an improvement over the linear predictions of the Rayleigh distribution, it cannot capture higher order nonlinear interactions or breaking. Both these mechanisms are relevant in deep, intermediate, and shallow water depths, but their significance is conditional on the magnitude of the storm. These effects are accurately described by the new model as indicated in the 2 subplots of Figure 1. Considering sea-states with the same deep-water steepness (S_1), subplot (a) shows that the largest crest heights lie above the second-order predictions. These relate to nonlinear amplifications of crests. In contrast, subplot (b) shows that at a shallower water depth the fully nonlinear results lie below second-order predictions. This effect is due to wave breaking.

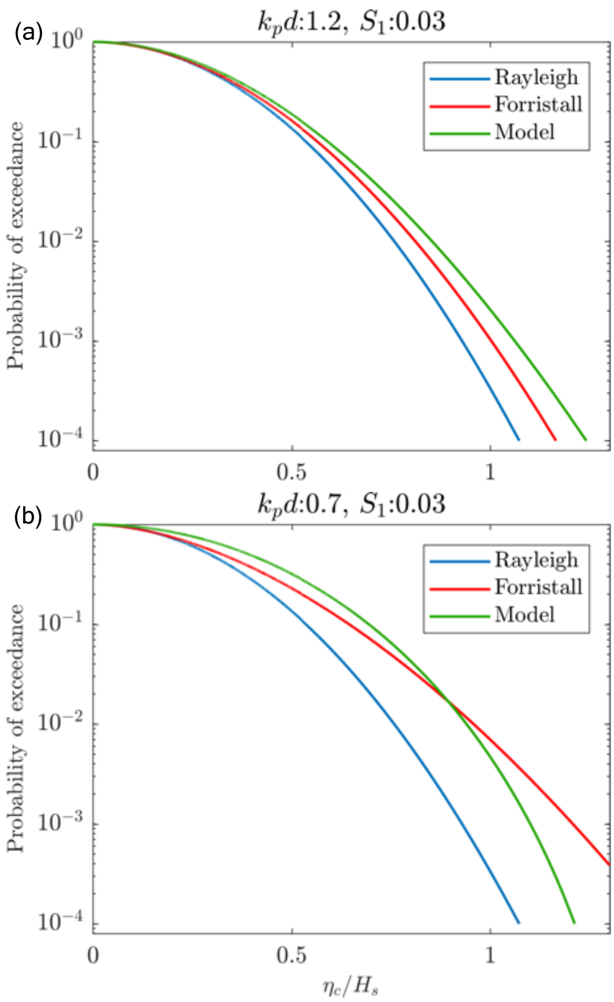

Figure 1. Comparisons between linear (Rayleigh), second-order (Forristall) and present model predictions. These correspond to sea-states with the same deep-water steepness (S_1) but different effective water depths ($k_p d$).

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Statistical Distribution of Free Water Surface over a Mild Bed Slope for Extreme Wavefields

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ABSTRACT

This paper examines the probability density function (PDF) of free water surface elevations in coastal areas. The functional form and properties of PDFs of extreme storms propagating over a mildly sloping bathymetry are investigated. This is facilitated through comparisons between experimental measurements and a wide range of probability models; the latter including both analytical and empirical distributions. The incident wave conditions correspond to realistic storm spectra (JONSWAP) and have been simulated as long random timeseries of 60-hour duration. The length of the records is sufficient to provide an accurate description of distribution tails. Six sea-states with varying offshore steepness have been generated and measured at different cross-shore locations. The cross-shore evolution of the wavefield initially leads to the development of nonlinear harmonics, both at low and high frequencies, and a broadening of the wave spectrum. This is enhanced by wave breaking particularly at shallower water depths or steeper sea-states. These result in rapid deviations from Gaussian theory with respect to the PDFs of surface elevations. Available models are generally successful in capturing nonlinear evolution arising at a second order of wave steepness but cannot model the probability structure once a significant proportion of waves are breaking. In comparing the deviations between experimental data and model predictions, the best performing model is identified.

INTRODUCTION

The efficient design of coastal and offshore structures directly depends upon the appropriate description of the design wavefield. Most commonly, the statistical distributions of zero-crossing quantities, such as wave heights and crest heights, are used to infer relevant kinematics and calculate design wave loads and responses. The PDF of water surface elevations provides the means to derive the distributions of zero-crossing waves. While Gaussian theory has been traditionally applied to approximate the PDF of water surface elevations, waves in coastal regions have a strong nonlinear behaviour and are prone to breaking. As such, more advanced models are required to provide an accurate representation of measured PDFs. Such models are discussed in the present paper and their accuracy is assessed on the basis of experimental data.

RESULTS

The present work provides a re-analysis of the experimental data produced by Katsardi et al., (2013) on a 1/100 bed slope. The metocean conditions defining the test cases are described in Table 1 and correspond to extreme sea-states which exhibit different degrees of nonlinearity and breaking saturation. Importantly, the occurrence of wave breaking varies across different cases which allows the investigation of both steepness and depth induced breaking.

Table 1. Sea-states defined using the offshore significant wave height ($H_{s,0}$) at $d = 50$ m and steepness $\left(\frac{H_{s,0}k_p}{2}\right)$.

Case	$H_{s,0}$ $[m]$	$0.5\,H_{s,0}k_p$
Tp12s	7.7	0.115
Tp12m	12.4	0.183
Tp12l	14.7	0.225
Tp15s	7.9	0.088
Tp15m	12	0.133
Tp15l	14.7	0.163

Available models have been assessed using the methodology outlined by Karmpadakis et al., (2020). The best performing models under the wide range of conditions and water depths are defined using an integral probability divergence measure and the experimental data. The recently proposed analytical model derived by Tayfun and Alkhalidi (2020) has been shown to provide accurate predictions for a wide range of cases. Regarding the cross-shore evolution of the PDF with reducing water depth, shown in Figure 1, the proposed model can capture progressively skewed structure of the distribution. Overall, this and other models can describe nonlinear wavefields that are not breaking with some success. However, no model could accurately describe the measured PDFs for breaking saturated conditions.

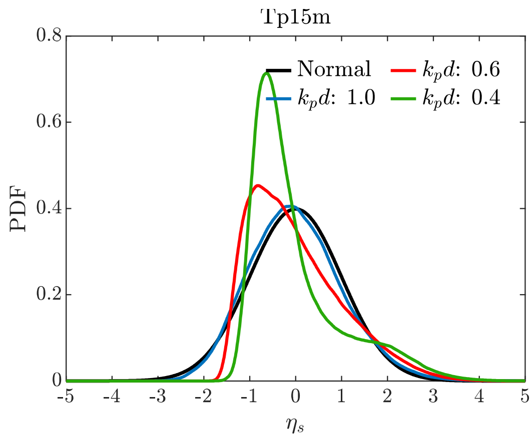

Figure 1. Evolution of PDF of surface elevations with reducing water depth. The measured data are compared to the Normal distribution.

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Spatial Evolution of Wave Height and Crest Height Distributions of Waves Propagating over Sloping Coastal Bathymetry

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ABSTRACT

This paper concerns the cross-shore evolution of the statistical distributions of zero-crossing wave heights and crest heights associated with surface waves propagating over sloping beds. These are investigated through the analysis of laboratory data involving long random wave simulations in realistic sea-state conditions. Specifically, experimental simulations have been designed to isolate the contributions of key metocean parameters, such as the incident wave steepness, effective water depth and seabed slope. Taken together, the results presented herein provide in-depth insights regarding the effects of nonlinearity, reduced water depth, bathymetric configuration, and the dissipative effect of wave breaking on the statistical behaviour of wave heights and crest heights. These results have important practical implications for the design of coastal structures and operation of marine vessels.

INTRODUCTION

The short-term statistical distributions of wave heights and crest heights in extreme sea-states across a broad range of effective water depths and incident wave conditions has been notoriously challenging to capture. This has resulted in large uncertainty in the estimation of design conditions for many offshore and coastal installations. Karmpadakis et al. (2020) highlighted that no single wave height model provides the best statistical description across a wide range of effective water depths and incident wave steepnesses. In addition, Katsardi et al. (2013) argued that none of the existing models can accurately describe the distribution of wave heights for the shallowest water depths. Building upon these results, the present study aims to provide physical insights into the evolution of the distributions of waves as they propagate towards the shoreline.

METHODOLOGY

The methodology follows the phase-alignment approach described by Karmpadakis et al. (2019). Unidirectional random waves propagating over a uniform bed slope were sampled using a densely-packed array of sensors. The fine spatio-temporal resolution of the measurements is paramount to the quantification of competing physical processes: the latter refer to the mechanisms of nonlinear amplification and wave breaking, as well as their dependence on the investigated parameters. The experimental cases are presented in Table 1. They correspond to 6 sea-states of increasing offshore steepness propagating over 3 seabed configurations. The water depth regime ranges from intermediate to shallow, and the sea-states cover near-linear to highly nonlinear storms.

DISCUSSION

To isolate the individual contributions, comparisons are performed between cases while varying the parameter of interest. Such a comparison is presented in Figure 1. For a

Table 1. List of experimental cases.

Sea-state	T_p [s]	H_s [m]	$1/2H_sk_p$[-]	s [-]	k_pd [-]
A1		0.029	0.035		
A2		0.057	0.070		
A3		0.086	0.105	0	1.22
A4	1.4	0.115	0.140	1/15	⋮
A5		0.139	0.170	1/50	0.48
A6		0.156	0.190		

selected bed slope and sea-state steepness, the evolution of the wave height and crest height distributions is examined. A progressive increase in crest heights is observed in the bulk of the distributions. This is explained by the enhancement of the nonlinear characteristics of waves as the water depth reduces; manifesting as higher and steeper crests and shallower and flatter troughs. Conversely, the tail of the distributions exhibits a downward shift with a reduction in the largest crest heights. This is attributed to the increased importance of wave breaking. A similar limiting trend is observed for wave heights. However, its onset occurs at progressively higher exceedance probabilities, leading to a substantial reduction in the tail of the distributions. By extending this analysis to the full range of effective water depths, and for different sea-state steepness and bed slope combinations, the relative importance of each individual parameter is determined.

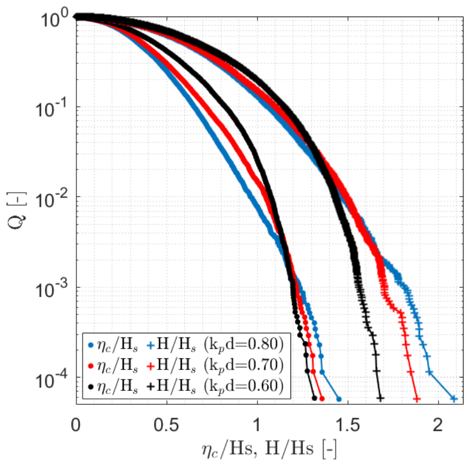

Figure 1. Normalised crest height (η_c/H_s) (●) and wave height (H/H_S) (+) distributions for selected effective water depths (k_pd). All cases presented refer to bed slope s=1/50 and offshore wave steepness $1/2H_sk_p$=0.105.

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Assessment of Extreme Sea State Conditions for Offshore Aquaculture Projects

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INTRODUCTION

The investigation of metocean climate conditions is of utmost importance for the successful design of offshore aquaculture systems. The study area has coordinates of 37.90° N – 24.50° E and is located to the south of the uninhabited islet of Mantilou, see and the associated map. The depth in the study area ranges between 95 m and 100 m, with relatively mild bathymetry. The area is in a short distance from important harbors (Karystos and Lavrio) and is close to the important fish market of Keratsini (Piraeus). In addition, this location is away from the passenger ships routes, while the wider area is characterized by a relatively mild to moderate wave and wind regime.

The wind data (wind speed and direction at 10 m above sea level) that are used in the analysis, have been derived from the ERA5 reanalysis product of the ECMWF (European Centre for Medium-Range Weather Forecasts) and is the most up-to-date reanalysis available today. The duration of the time series used covers a period of 16 years (2005-2020). The wave data is a hindcast product of the Mediterranean Sea Waves forecasting system, which is based on the third-generation WAM Cycle 4.5.4 wave model, for the period 2006–2018. The spatial and temporal resolution of the model is 1 h and 1/24° x 1/24°, respectively.

WIND AND WAVE CLIMATE

The wave climate of the area is mild, with an average value of significant wave height H_S of 0.6 m and an average spectral peak period T_P of 4.7 s. The prevailing sea state directions are NNW and SW. During winter (December-January-February) the highest values of mean H_S and T_P occur, exceeding 0.7 m and 5 s respectively, while the lowest values occur in May and June during which the mean values of H_S do not exceed 0.4 m and the mean values of T_P range between 4 s and 4.2 s. The wind climate of the area is relatively intense. The most intense wind speeds occur during January, February and August. The prevailing wind directions are NNW and SE, while the strongest winds in the area blow from the N, NW, NW and SW directions. On a monthly basis, wind climate is affected by the etesian winds during the summer months. The maximum value of U_W is ~19.14 m/s, while the long-term mean value is ~5.79 m/s.

DIRECTIONAL EXTREME VALUE ANALYSIS OF H_S

Since the dynamic behavior of marine structures strongly depends on the directional characteristics of sea states, directionality is taken into account as a covariate in the estimation of the $n-$years design value of H_S, see e.g. (Philippe et al., 2013). The modeling of the extreme values of H_S is based on the Generalized Pareto (GP) distribution with its unknown parameters expressed this time as a function of sea-state direction θ, as proposed by Jonathan & Ewans (2007). In this context, the form of the GP distribution is as follows:

$$G(y;\xi,\sigma^*) = 1 - \left[1 + y\frac{\xi(\theta)}{\sigma^*(\theta)}\right]^{-1/\xi(\theta)}, \sigma^* > 0, \quad (1)$$

for $y > 0$, $1 + y\frac{\xi}{\sigma^*} > 0$ and $\sigma^* = \sigma + \xi(u - \mu)$, when $\xi \neq 0$. In the above relation ξ and σ^* are the shape and scale parameters, respectively. u is an appropriately defined threshold value that allows the GP distribution to be used to describe extremes. To describe the directional dependence of the unknown σ^* and ξ parameters, a Fourier series extension was applied, which ensures a relatively smooth periodic behavior of these estimates with respect to wave direction θ. The general form of the Fourier series for the parameters ξ and σ^* is given as follows:

$$\sum_{k=0}^{p}\sum_{b=1}^{2} A_{bk} t_b(k\theta) \text{ and } \sum_{k=0}^{p}\sum_{b=1}^{2} B_{bk} t_b(k\theta), \quad (2)$$

respectively, where $k = 0, \dots, p$ denotes the order of the Fourier model, A, B are the unknown coefficients for the parameters ξ and σ^*, respectively, and t_1, t_2 are the functions of sine and cosine, respectively. Indicatively, for the Fourier 1st order model, six unknown coefficients should be estimated with the parameters ξ and σ^* taking the form:

$$\xi(\theta) = A_{10} + A_{11}\cos\theta + A_{21}\sin\theta \text{ and } \sigma^*(\theta) = B_{10} + B_{11}\cos\theta + B_{21}\sin\theta \quad (3)$$

The unknown coefficients A_{bk} and B_{bk}, $b = 1,2$, $k = 0, \dots, p$, are estimated by applying a penalized maximum likelihood method, proposed by Karathanasi et al. (2020). In the following figure, the design values of 20, 50 and 100 years for H_S in relation to the wave direction θ are presented. For a return period of 50 years, the highest design value of H_S (5.82 m) corresponds to the SSW sector [183°,190°] and the second highest value (5.39 m) to the NNE sector [26°,30°].

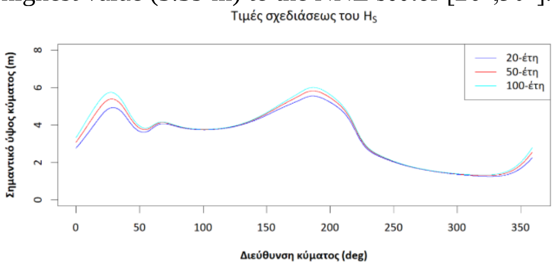

Figure 1. Directional design values of H_S

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Using a Multivariate Stochastic Model to Reproduce Existing Wave Data

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INTRODUCTION

Joint time series of wave height, period and direction are essential input data to computational models which are used to simulate diachronic beach evolution in coastal engineering. However, it is impractical to collect a large amount of the required input data due to the expense. Based on the nearshore wave records offshore of Littlehampton in south-east England over the period from 01/07/2003 to 30/06/2016, this work presents a statistical method to obtain simulated joint time series of wave height, period and direction covering an extended time span of a decade or more. The method is based on a vector auto-regressive moving average algorithm.

METHODOLOGY

The Methodology followed in this work can be summarized in the following flow diagram:

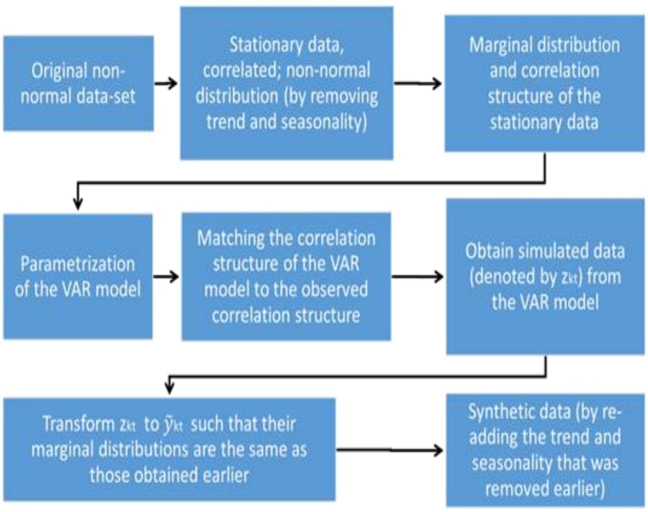

Figure 1. Data processing via the proposed stochastic model to create synthetic time-series.

CASE-STUDY

For our test case we have chosen Littlehampton which is located in south-east England:

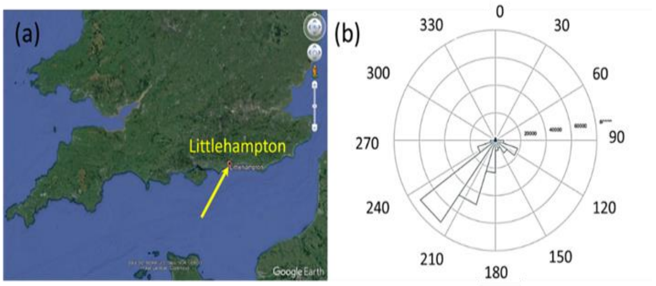

Figure 2. Our case-study is located in southern England.

SIMULATION RESULTS

The thirteen years of measurements at Littlehampton were detrended and deseasonalized. The marginal distributions of wave height, period and direction and their autocorrelations and cross-correlations were estimated from this sequence. The length of the simulated data was taken to be the same as the original series for illustration purpose. Finally, the trend and seasonality removed in the initial steps were added back to create the output synthetic time-series.
If the method is working well the simulated data should have similar statistical properties to those of the original data. As a check on this, marginal distributions and correlations of the original and simulated series were compared. The marginal distributions of the observed and simulated data were estimated with the non-parametric kernel estimation method. The estimated marginal density functions are given in Figure 3, where the black curves correspond to the observed data and the red curves correspond to the simulated data. It can be seen that the two sets of density functions are very close for all three sea condition variables:

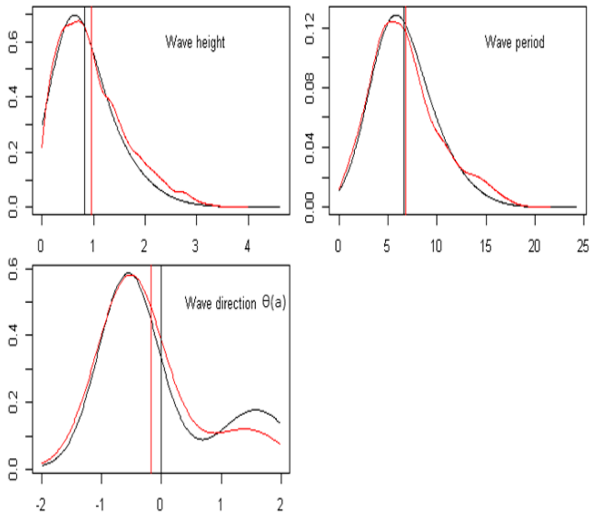

Figure 3. Density function plots for the observed and simulated wave height (m), wave period (s) and wave direction (dimensionless transformed) respectively. (Valsamidis et al., 2022).

CONCLUSIONS

The simulated times series show a satisfactory degree of stochastic agreement between original and simulated time series, including average value, marginal distribution, autocorrelation, and cross-correlation structure, which are important for Monte Carlo modelling of shoreline evolution, thereby allowing ensemble prediction of shoreline response to a variable wave climate.

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Hydrodynamic Loads and Fatigue Design of Large Rated Fixed Bottom Offshore Wind Turbines

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ABSTRACT

Rapid development and readiness boost in Offshore Wind Turbines (OWTs) technology have occurred over the past ten years globally. OWTs technology can be considered as the leading technology in the offshore renewable energy sector and have the largest potential of becoming the backbone of the energy system by 2030. OWTs technology already is considered as a fully developed commercial solution. By the end of 2021 the global cumulative offshore wind power capacity has reached 56 GW. A year-over-year increase growth equal to 58% has been achieved within 2021 and 21.1 GW of new installations have connected to the grid globally (GWEC, 2022).

Up to now, the use of fixed bottom OWTs dominates against the use of floating OWTs mainly due to the lower Levelized Cost of Energy that fixed bottom OWTs present and due to engineering issues related to smaller number of uncertainties in their design. Different possible types of foundations (e.g. monopiles, jackets, tripods) can be used to support wind turbines depending mainly on the water depth but also on the local site environmental conditions. Monopiles are the most widely used foundations for fixed bottom OWTs and intermediate waters because of low cost, easy installation and maintenance processes. Monopiles remain the most frequently installed foundation, with more than 90% of the total installed foundation to date in Europe (WindEurope, 2022).

Similarly to 2021 and following this marvellous trend, the contribution of offshore wind power to the energy mix is expected to boom significantly by 2030. Fixed bottom OWTs and monopiles will remain as the dominating utilized technology for the years to come. Relevant reports (GWEC, 2022; WindEurope, 2022) are highlighting the need for parallel technological advancement in fixed bottom OWTs accompanied by an increase in the capacity of OWTs targeting to ultra-large OWTs with capacity larger than 5 MW. This need already results to a relevant huge challenge for the design and maintenance of large diameter monopiles for serving as foundations to the ultra-large fixed bottom OWTs. Currently, with the increasing rated power capacity of the OWTs, it is very common the need for utilization of monopiles around 10 m diameter.

As moving from shallow to deeper waters in connection with larger turbines and supporting infrastructures the technical feasibility of the monopile will be challenged, particularly, as wave loads increasingly interact with the response and integrity of the OWTs. The diameter of fixed bottom monopile OWTs is one of the important factors affecting their hydrodynamic performance, while, the interaction between nonlinear waves and the monopile is particularly prominent. The effect of diffraction of waves will become increasingly important.

Support structures of OWTs are extremely vital components in their design, as damage or failure of them can lead to the loss of the complete OWT. The slenderness of monopile OWTs combined with the highly dynamic environmental loadings have resulted in structures which must be carefully designed against ultimate and fatigue failure. Even when the wave and wind loads are resulting to lower than the yield stress response, the sheer number of load cycles over the lifetime of an OWT may lead to failure. For this reason, it is important to consider the fatigue damage when designing OWTs and evaluate their Fatigue Limit State.

The effect of the method used for computing hydrodynamic loads on the fatigue design of a large diameter fixed bottom OWT is examined in the present paper. Three different efficient methods for computing hydrodynamic loads are considered and compared. Those methods are (a) the Morison's equation (Morison and Johnson, 1950) with undisturbed linear wave kinematics, (b) Morison's equation with undisturbed second order Stokes wave kinematics and (c) the MacCamy-Fuchs model (MacCamy and Fuchs, 1954) which is able to account for diffraction in waves. Initially the models are compared in terms of the hydrodynamic loading calculation against relevant experimental data and wave conditions. Afterwards, the hydrodynamic loads models are integrated within a software tool for solving the fully coupled dynamic equation of the OWT.

The responses and fatigue life of the large-rated OWT due to environmental loadings are investigated using the coupled analysis tool and compared. Fatigue damage is estimated based on the axial internal loads in the monopile and tower. The fluctuating responses obtained from the analysis tool are broken down into individual stress cycles using the rainflow counting approach. The fatigue damage is assumed to accumulate linearly with each of the load cycles and calculated according to Miner's rule with thickness effects included. Fatigue life of the OWT is estimated for a specific site in the Aegean Sea, Greece. The importance of including diffraction effects in the fatigue design calculation is emphasized with the comparative study.

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Numerical Investigation of Wave-Induced Seabed Response around a Monopile Foundation

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INTRODUCTION AND OBJECTIVES

Offshore wind has favoured the use of monopile foundation due to its simplicity in design, construction and industrial scalability. The stability of the monopile foundations can be affected not only by the direct action of wave loads but also by the response of the surrounding seabed. Numerical modelling can be used to simulate the wave-structure-seabed interaction and accurately predict the wave-induced seabed response around the monopile foundation. Within this context, a 3D integrated numerical model is developed to investigate the excess pore water pressure development around the monopile foundation and the accompanying changes in the effective stress of the seabed soil. In addition to the coupled hydrodynamic-geotechnical analyses, in-situ monitoring data are available to the SOILTWIN project, which provide insight in the soil behaviour around the monopile foundation for various wave loading conditions. The comparison of the numerical results with in-situ monitoring data is essential for an improved calibration of the soil response to the observed behaviour in-situ.

NUMERICAL MODEL

The hydrodynamic numerical model is developed using OpenFOAM®, an open source Computational Fluid Dynamics (CFD) software (Figure 1). The olaFlow open source solver is implemented to allow for wave generation and absorption at the boundaries. The wave domain is governed by the three-dimensional Volume Averaged Reynolds Averaged Navier-Stokes (VARANS) equations for two incompressible phases (water and air) using a finite volume discretization. The volume of fluid (VOF) method is applied for the free surface tracking. The seabed model is developed in ABAQUS, a finite element software, to investigate the wave-induced dynamic response of the poroelastic seabed, considering the inertia effects and the compressibility of solid and pore fluid. The wave induced pore pressures at the seabed surface are obtained using the three dimensional hydrodynamic model and are applied as a boundary condition to the seabed model. In the present work, one way coupling is applied, due to the fact that the movement of the monopile and the seabed transformation are considered to have negligible effects on the wave propagation.

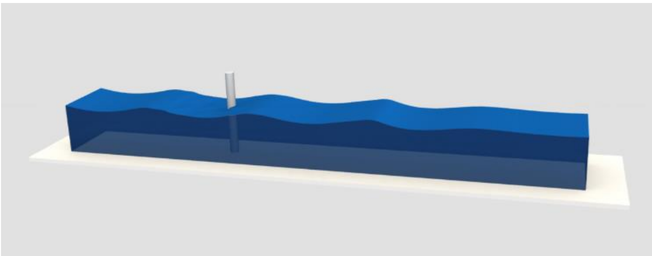

Figure 1. Hydrodynamic numerical model in OpenFOAM.

RESULTS

First achieved results show that the presence of the embedded monopile foundation causes a local increase of the effective soil stress below the foundation. Moreover, the inserted pile foundation considerably modifies the distribution of pore water pressures in the seabed; namely, the maximum pore water pressure increases around the foundation and decreases below the monopile. Based on these results the liquefaction depth due to the presence of the monopile for various wave conditions can be determined. Furthermore, the comparison of the numerical results with in-situ monitoring data can provide a better understanding of the mechanism of wave induced soil response around the monopile foundation and result in a high fidelity, calibrated numerical model.

CONCLUSIONS

In this study, a three dimensional numerical model is developed based on a VARANS wave model and a poroelastic seabed model using one-way coupling. The wave induced seabed response and, more specifically, the pore pressure development and effective stress distribution around the monopile foundation are investigated. The unique datasets available to this project allow for a data-driven approach which is built up around in-situ monitoring data of the foundation piles.

ACKNOWLEDGEMENTS

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Design and Time-domain Analysis of a 10 MW Semi-submersible Floating Offshore Wind Turbine

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INTRODUCTION

Floating Offshore Wind Turbines (FOWTs) play a leading role in the renewable energy technology towards a low-carbon future in Europe. Those structures are designed to operate at large water depths, where stronger winds exist. Therefore, WTs of large capacity can be deployed. Motivated by this, the present paper focuses on the design of a new 10 MW semi-submersible FOWT and its preliminary time-domain analysis using OpenFAST.

DESIGN OF THE FOWT

The examined FOWT consists of the DTU 10 MW reference WT with the relevant tower (Yu et al., 2017) and a semi-submersible floating platform, having a central column, 3 side columns and 3 interconnected submerged pontoons (Figure 1). The design of the platform is based on the upscaling of an existing 5 MW FOWT (Michailides et al., 2014), by using the following scaling factor, where $m_{WT,10MW}$ and $m_{WT,5MW}$ are the mass of the 10 and 5 MW WT respectively.

$$k = \sqrt[3]{m_{WT,10MW}/m_{WT,5MW}} \quad (1)$$

In order to fit, though, the central column to the tower base, the k_M scaling factor has been used for this column, as defined by Eq. 2, where $D_{tower,10MW}$ and $D_{tower,5MW}$ are respectively the diameter of the tower base for the 10 and 5 MW WT. Some geometrical arrangements required the consideration of k_M also for the side columns.

$$k_M = D_{tower,10MW}/D_{tower,5MW} \quad (2)$$

The final draft of the FOWT was selected equal to 35 m, while, it is noted that the tower of the DTU 10 MW WT has been appropriately adjusted to fit to the final geometry of the platform. As for the mooring system, designed for 100 m water depth, it consists of 3 catenary mooring lines of studless chains.

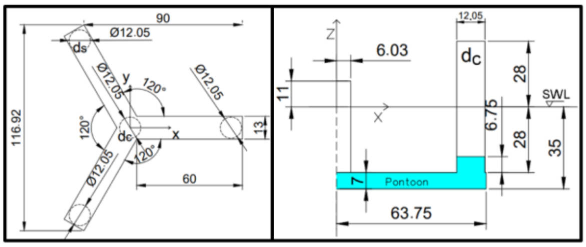

Figure 1. Top and side view of the proposed platform.

TIME-DOMAIN ANALYSIS OF THE FOWT

The integrated time-domain analysis of the proposed FOWT in OpenFAST aims at: (a) identifying important static and intrinsic dynamic features of the FOWT and (b) assessing the FOWT's performance under various wind and wave load cases. Table 1 shows the results of the implemented static equilibrium tests, while the natural frequencies of the platform as resulted from free decay simulations are cited in Table 2. Finally, in Figure 2 the time-series of some quantities describing the FOWT's performance are shown indicatively for a load case with $U_{w,RNA}$ =17.9 m/s, H_s =1.95 m and T_p =4.86 s.

Table 1. Static offset of the FOWT.

Surge (m)	Heave (m)	Pitch (deg)
0.0203	-0.1909	-0.0728

Table 2. Natural frequencies (Hz) of the platform

Surge	Sway	Heave	Roll	Pitch	Yaw
0.0049	0.0049	0.0433	0.4028	0.4028	0.0055

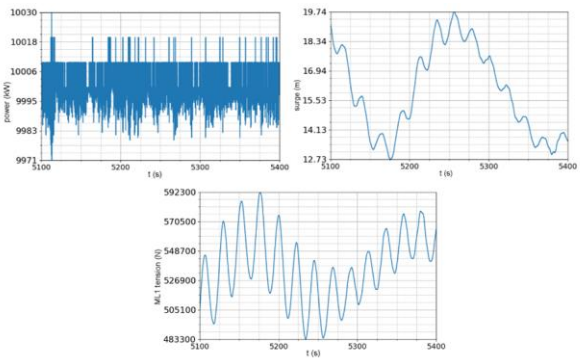

Figure 2. Power, surge and mooring line tension time-series.

MAIN CONCLUSIONS

The results of the present paper indicate an efficient design of a new 10 MW semi-submersible FOWT that meets some of the main design requirements of this kind of floating systems (e.g. natural frequencies within required limits, anticipated dynamic responses and power production). Further work is required including a more detailed mooring system design and an extensive assessment of the FOWT's performance under various load cases for different limit states.

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Wave Trapping Phenomena in an Array of Bottom-Seated Surface-Piercing Porous Cylinders

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INTRODUCTION

Porous structures have been widely studied due to their effectiveness at dissipating the unwanted wave energy. By comparing with the impermeable bodies, both the transmitted and reflected wave heights are relatively reduced, whereas the wave loads on porous structures are decreased. Hence, they become preferable due to their porosity, for applications such as harbor and shore protection (Sollitt & Cross, 1972, 1976; Madsen 1972; Sulisz 1985).

At the same time, there is a considerable interest in hydrodynamic interactions between multibody impermeable arrangements due to the diffracted and scattered waves that create the so called trapped-mode phenomenon (Ursell, 1951; Callan et al., 1991). The latter is connected with the wave trapping in the fluid region between adjacent bodies, forming a near-standing wave with much larger amplitude compared to the waves at other wave frequencies, whose energy slowly leaks away to infinity. Maniar & Newman (1997) associated the existence of trapped waves in a channel with near-resonant modes occuring between neighbourhood impermeable bodies with critical spacing. In these modes the diffraction loads are remarkably increased compared to the forces on a body in isolation.

The present paper takes a further step dealing with the same problem, enhanced however, with the existence of porous structures in the vicinity of the array. The 3D water-wave diffraction problem by arrays of bottom-seated and surface piercing porous cylinders is formulated and solved, whereas the existence of trapped waves is studied against the porosity parameter.

PROBLEM FORMULATION

An array of N porous vertical cylinders is assumed to be placed on the seabed, extending beyond the undisturbed free surface (see Figure 1). The bodies are exposed to the action of a plane incident wave of frequency ω and amplitude A. A theoretical formulation is presented, which is suitable for solving the linearized diffraction problem around the array in the frequency domain. The solution is based on the eigenfunction expansion method, in which analytical representations of the velocity potential are derived through the idealization of the flow field around each body. The condition on the porous boundary is defined by applying Darcy's law, whereas the fluid velocity and its derivatives are matched at the common boundaries of adjacent fluid domains by enforcing appropriate continuity conditions. The fluid is assumed non viscous and incompressible and the flow irrotational, so that the linear potential theory can be employed.

Regarding the wave interaction phenomena between the array members and the incoming waves, the multiple scattering approach has been assumed. The latter is based on the superposition of the incident wave potential and various orders of propagating and evanescent modes that are scattered and radiated by the array members (Twersky, 1952; Mavrakos & Koumoutsakos, 1987).

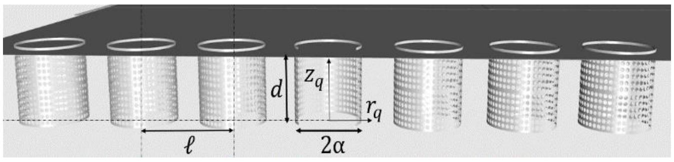

Figure 1: 3-D representation of the examined array of permeable cylindrical bodies

CONCLUSIONS

The present work focuses on the so called "near trapping" mode phenomena, created by an array of finite length, supplemented by representative numerical results for various porosity parameters and distances between the bodies concerning the exciting loads on the porous cylinders. The main conclusion drawn from the study is the reduction of the wave amplitude around adjacent bodies, which is strongly affected by the porosity of the side surfaces of the cylinders.

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Numerical Modelling of a Floating Hybrid Offshore Wind and Wave Energy System by Utilizing the Generalized Modes Approach

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INTRODUCTION

Offshore wind and wave energy comprise two of the most important renewable energy sources in the marine environment. Their efficient exploitation, directly related to the EU energy policies, can contribute to energy security enhancement, economic growth and reduction of greenhouse gas emissions. Accordingly, many large-scale commercial offshore wind farms have been installed and operating in Europe, while, during the last years the Floating Offshore Wind Turbines (FOWTs) technology is rapidly growing, giving access to deeper waters, where stronger and more consistent winds exist. Regarding wave energy, a variety of Wave Energy Converters (WECs) with different working principles have been investigated, developed and tested so far aiming to overcome existing technological barriers and achieve competitiveness with other renewable energy sources. Irrespectively of the above developments, costs reduction still presents a challenge that both the offshore wind and the wave energy sectors share. It may, thus, be beneficial to deploy floating Hybrid Offshore Wind and Wave Energy Systems (HOWiWaESs) that enable the simultaneous exploitation of the corresponding energy potentials in deep waters by combining in one structure an offshore wind turbine with WECs. Up to now, different concepts of HOWiWaESs have been proposed by various researchers (e.g., Muliawan et al., 2013; Karimirad and Michailides, 2018), who investigated the performance (dynamic behavior and power production) of those systems by developing adequate, case-specific, time-domain numerical models based on the multi-body approach.

In the present paper, a generic numerical tool for analyzing in time-domain the performance of floating HOWiWaESs under the combined wind and wave action is developed and validated. Contrary to existing studies, the whole system is modeled as one structure with six Degrees of Freedom (DoFs), while the motions of the WECs relatively to the FOWT are described as additional DoFs by utilizing the generalized modes concept (Newman, 1994).

NUMERICAL TOOL

The proposed in the present paper numerical tool for the time-domain analysis of a floating HOWiWaES is developed by modifying and extending appropriately the aero-hydro-servo-elastic open-source code Open-FAST (Jonkman and Buhl, 2005). Specifically, the Cummins equation of motion deployed in Open-FAST is extended to account for the additional generalized DoFs, while subroutines are developed for the Power Take Off (PTO) mechanisms of the WECs. The hydrodynamic coupling between the FOWT and the WECs is taken into account through the inclusion of non-zero non-diagonal hydrodynamic and hydrostatic coefficient matrix terms in the equation of motion.

The frequency-dependent exciting forces and hydrodynamic and hydrostatic coefficients are initially calculated in the frequency domain using WAMIT software (WAMIT Inc., 2006) that is based on the traditional boundary integral equation method. The mode shapes of the generalized DoFs required for this frequency-domain analysis, are determined be developing appropriate vector shape functions. It is noted that this generalized modes concept can take advantage of the layout's symmetry, providing a faster and more effective way for obtaining results.

VALIDATION OF THE NUMERICAL TOOL

The numerical tool is validated by comparing results with the numerical ones obtained by Karimirad and Michailides (2018) for the case of the so-called "Wind-WEC" hybrid system. The examined system consists of a 5 MW OWT with a spar floating platform and a conic WEC buoy hinged on it via a mechanical arm. Accordingly, we account for a 7 DoFs system. Validation is performed for various wind and wave conditions, while comparisons are made in terms of responses (i.e., surge, heave and pitch) and produced power.

CONCLUSIONS

In this paper, a generic numerical tool for the time-domain analysis of floating HOWiWaESs is developed and validated for the case of a simple hybrid system with one WEC. The good agreement between the results of the present tool with those obtained from other investigators, who utilized the multi-body approach, indicate the potential of the aforementioned tool to efficiently model floating HOWiWaESs. Items for future research include further development of the proposed tool to account for multiple WECs and relevant comparison with available numerical and experimental results.

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2D Numerical Hydrodynamic Validation of Very Flexible Floating Solar Platforms

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INTRODUCTION

Scaling up energy production from renewable resources is an imperative need to meet future energy demands. A novel approach to ramp up production of renewable energy is the use of offshore floating photovoltaics (OFPVs), deploying land-based renewable solar technologies to offshore platforms. The current state of the art OFPVs prototypes lack any design standards for environmental loads, while they employ as proxy the design basis of the offshore oil and gas (ONG) industry. Contrary to the very large and stiff offshore ONG structures, the OFPVs conceptual designs use thin, lightweight and very flexible materials (Trapani and Millar, 2014), leading to inefficiencies when adapting ONG standards to capture device specific behaviors. OFPVs are characterized by structural flexibility and large deformations which are dominant in comparison to the rigid body motions. Thus, significant consequences are introduced on the overall structural robustness and fatigue integrity of the floating structure (Loukogeorgaki et al., 2014).

In order to design and assess the survivability of flexible offshore floating structures (OFSs), the related hydrodynamic forces, the floating body motions and the structural deformations have to be modelled. Simplistic approaches based on linear models and analytical equations to determine the hydrodynamic forces on the floating structure, disregard the hydroelastic performance of the OFSs. Such approaches may be based on the Morrison equation, and on potential flow theory to model the hydrodynamic flow (Al-Yacouby et al., 2020; Ikhennicheu et al., 2021). The hydroelastic response of the OFSs needs to be addressed with fully rotational time-domain non-linear models both for structural dynamics and hydrodynamics.

To address the described knowledge gaps, the current research employs the coupling between a smoothed particle hydrodynamic (SPH) solver for the fluid domain (DualSPHysics) and a finite element analysis (FEA) library for the structure (Project Chrono).

METHODOLOGY

The existing coupling between DualSPHysics and Project Chrono facilitates fluid-structure interaction (FSI), of solely rigid body motion for the floating objects. In the presented research, the capabilities of the coupling are extended by establishing the rigid finite element method (Wittbrodt et al., 2006) for floating bodies. This framework describes a flexible element as multiple rigid bodies interconnected with spring-damping elements, which are referred to as flexible links. The properties of the flexible links, stiffness coefficients and damping coefficients, are calculated based on the material properties and the geometrical dimensions of the floating structure and can therefore replicate the elastic response of a flexible element. For the current research, an innovative 2D flexible floating beam is developed with hinged links connecting the rigid floating bodies, allowing only surge, heave and pitch motion for the floating platform.

VALIDATION

The numerical model is validated using wave flume experiments conducted by Brown et al. (2022). A floating beam with length $L = 0.96$ m, Young's modulus $E = 5.65\text{x}10^5$ Pa and Poisson's ratio $v_s = 0.49$ is tested under regular wave attack with wave height $H = 0.018$ m and period $T = 1.04$ s. The numerical beam is discretized into 20 rigid bodies, while a particle resolution of $dp = 0.001$ m is selected. The vertical displacements dz for different characteristic points of the structure are depicted in Figure 1 as function of x/L, where x is the horizontal local coordinate of each point, and t/T, where t is the current simulation time. A reasonable agreement can be observed between the numerical beam and the experiments.

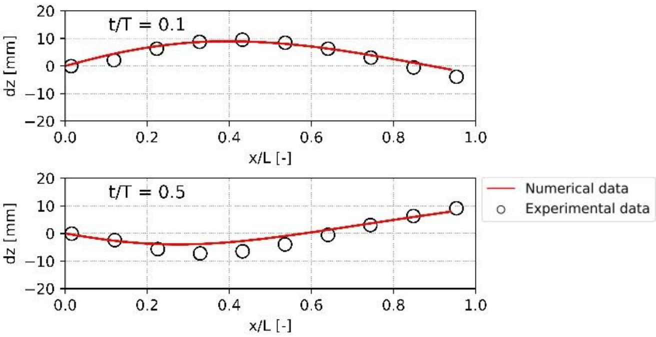

Figure 1. Vertical displacement dz of characteristic points of the beam, as a function of x/L and t/T.

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Time-domain Analysis of an Array of Heaving Wave Energy Converters in front of a Wall

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INTRODUCTION

Wave energy is a vast and abundant renewable energy source, with high energy density, limited negative environmental impact and larger consistency due to natural seasonal variability (Guo and Ringwood, 2021). Heaving Wave Energy Converters (WECs) with the "one-mode" operation simplicity correspond, nowadays, to one of the most technologically advanced WECs type. For absorbing an adequate amount of power, WEC arrays consisting of multiple devices have to be deployed either at offshore or at near-shore locations. In the latter case, the arrays may be integrated with existing wall-type (vertical) breakwaters, contributing to reduction of costs and advancement of WECs' maturity. Motivated by this, the present paper focuses on the time-domain numerical investigation of the performance (hydrodynamic behavior and energy absorption) of an array of heaving WECs in front of a bottom-mounted vertical wall.

NUMERICAL MODELLING

A linear array of M identical, semi-immersed, oblate spheroidal heaving WECs is placed in an area of finite and constant water depth d in front of a bottom–mounted, vertical wall of finite length, l_w, and negligible thickness t, at a distance c from it (Figure 1). The hydrodynamic analysis of this array, including hydrodynamic interaction effects between the WECs and between the wall and the devices, is performed in the time domain under the action of regular and irregular waves by deploying the WEC-Sim open-source code (Yu et al., 2014). The required for the analysis frequency-depended exciting forces and hydrodynamic coefficients are obtained from the solution of the corresponding diffraction/radiation problem in the frequency domain by utilizing the conventional boundary integral equation method.

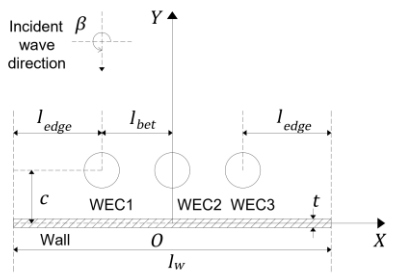

Figure 1. Geometry of the examined problem (*X*-*Y* plane)

CASES EXAMINED AND ILLUSTRATIVE RESULTS

The numerical analysis is implemented for an array of $M = 3$ devices with semi-major axis $a = 2.0$ m and non-dimensional semi-minor axis $b/a = 0.85$. The array is installed in front of a vertical wall with $l_w = 36$ m and $t = 1$ m in an area of $d = 10$ m. Focus is given on the effect of c on the performance of the array. Accordingly, two different c values are examined, equal to $1.5a$ (Case 1) and $3a$ (Case 2). The action of perpendicular to the arrangement waves is taken into account (i.e., $\beta = 270°$, Figure 1). Regular waves with height, H, equal to 1.0 m and T equal to 2.8 s, 3.0 s, 4.0 s, 5.0 s and 6.0 s are being examined, while for irregular waves, the JONSWAP spectrum is deployed with H_s varying between 0.5 m and 5.0 m with a 0.5 m step and T_p between 2 s and 6 s with a 1 s step.

Figure 2 shows indicatively the effect of c and T on the maximum value of the power absorbed by the array, P_{array}^{max}. It is clear that Case 1 array performs better at the three largest examined periods, while the opposite holds true for the periods closer to devices' heave natural period (equal to 2.6 s).

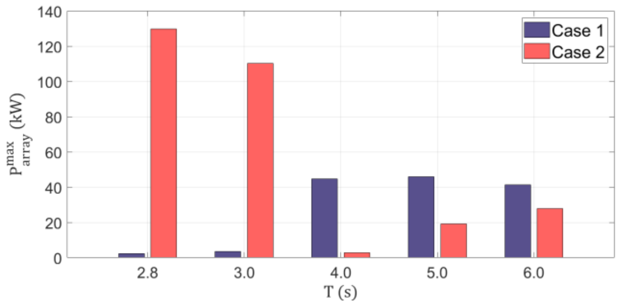

Figure 2. Effect of c and T on $Power_{array}^{max}$

MAIN CONCLUSIONS

The results of the present paper demonstrate that the wall-array distance corresponds to a very important design parameter, having a direct effect on the array's power absorption ability. When the WECs are situated close to the wall (c = 1.5a), the array's power absorption ability is not driven by resonance phenomena, since large power values of the bodies individually and, subsequently, of the array are observed at wave periods outside the range, where resonance occurs. The opposite holds true for the largest examined c value (1.5a), where the wall presence does not impose any restrictions on the amplification of the aforementioned quantities due to resonance.

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Assessing the Integration of an Oscillating Water Column at the Planned Genoa Breakwater

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Coastal regions in the Mediterranean are in immediate risk of Climate Change, sea level rise driving increases in extreme events, potential flooding and erosion (Makris et al., 2016). This can create severe problems for coastal populated areas, cities and the security of operations for crucial sectors such as harbors. Indeed, the Mediterranean shores are densely populated and about 20% of the world's seaborn commerce passes through the Mediterranean Sea.

The increasing pressure at Mediterranean coastlines requires to take adaptation measures and rethink coastal infrastructure design, embedding policies that pursue sectoral decarbonization and carbon neutral operations. These have been particularly developed over the past years, with leaders California, Shenzhen and the Port of Rotterdam (Samadi et al., 2016). Most of proposed solutions includes photovoltaic and onshore wind as sources of renewable electricity. However, wave energy production remains one of the most overlooked and under-utilized resource, with high synergies at coastal locations for power production, and coastal protection.

There are numerous wave energy converters (WEC) that can be selected for wave resource exploitation. Most commonly though, WECs are distinguished by their deployment applicability and are separated into shoreline, nearshore and deep water devices (Rusu and Onea, 2018). Knowledge of metocean conditions is vital to ensure the optimisation of any type of power take off for WEC, whether that is a linear generator or the optimisation of hydrodynamic characteristic for increased efficiency of an Oscillating Water Column.

The option to have an WEC integrated breakwater at the port of Genoa, ensures that the port will protect the area from harsh incoming waves but also contribute towards the port decarbonisation. However, in order for the solution to be viable, a first layer analysis has to estimate its profitability. This works uses a long-term high fidelity wave numerical model from 1979-2018, estimating the potential energy production for an integrated OWC at the Port of Genoa.

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Exploitation of Marine Wave Energy: Application in Selected Greek Coastal Areas

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ABSTRACT

Marine wave energy is a purely renewable form of energy. The exploitation and utilization of this energy is therefore of great value. The coastal structures that aim to capture and utilize this kind of energy are of great importance. Many researchers studied this specific topic during the last decades both experimentally and numerically (Stagonas 2010; Gravas et al, 2012; Sismani and Karampas 2015; Kralli et al. 2019). The present study is focused on the harnessing of wave energy by marine structures which are parts of a port or projects that may simultaneously serve other purposes, like coastal protection. For the implementation of the study, suitable locations are selected in the Greek coastal area, which are exposed to waves that have been propagated from a long sea distance so as to ensure the best possible result, in terms of energy potential. In particular, the aim is to select areas on the coasts of western as well as southern Greece. After the calculation of the wave characteristics by wave forecasting methods in combination with the wind climate of each region, a mathematical model is applied to simulate a suitable construction arrangement for capturing and utilizing the wave energy and then calculating the produced energy.

The model was developed by Professor Christopher Koutitas, in the mid-2000s. More specifically, it is a one-dimensional model for describing the propagation of a linear long wave along a channel with depth d, ending at a specific type of coastal engineering structure (breakwater or caisson) for harnessing the wave energy leading ultimately to electricity production. More specifically, the model simulates the propagation of a long linear wave along a 1D channel from a left boundary to the right boundary where a caisson wall (either a breakwater or a seawall) is located, absorbing the waves. At the same time, the tank inside the structure is filled with water, while the reservoir is evacuated with the water draining/ abducting to the side of the port or the coastal zone behind the breakwater wall through an opening and a pipeline. The basic equations that describe the propagation of the wave are the equations of conservation of momentum (equation of balance of forces) and conservation of mass (equation of continuity).

The form of the energy wall or breakwater is sketched in Figure 1. The symbols of figure 1 are as follows: D_o is the diameter of the caisson evacuation orifice charging the low head turbine, h_o: the water depth in the area (from the Mean Sea Level to the Bottom); h is the instantaneous water depth in front of the entrance of the reservoir (caisson); B is the width of the reservoir; R_c is the overtopped crest elevation, measured from the Mean Sea Level (MSL); H_{res} is the depth of the water inside the reservoir (caisson); thres is the elevation of the crest from the channel bed, equal to $[h_o+R_c]$, Δh_1 is the overtopping water head from the crest of the structure, equal to $[h – R_c - h_o] = h$ - thres, Δh_2 or H_m is the available pressure head equal to $[H_{res}-h_o]$

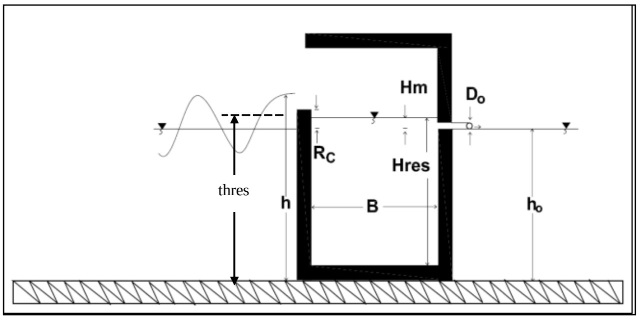

Figure 1. The “wave harnessing” coastal structure (Gravas et al. 2012)

The above research leads to useful results that show the possibility of exploiting the energy of sea waves in Greece.

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Special thanks to Hellenic National Meteorological Service that kindly provided us with the meteorological-wind data.

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Mean Drift Forces on Arrays of Vertical Porous Cylindrical Bodies

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INTRODUCTION

A floating body exposed to the action of incident waves experiences second order forces due to nonlinear effects, apart from the oscillatory loading components which cause the first-order motions of the body. These forces which are derived by the solution of the linearized body-wave interaction problem, performs zero mean values over one period. These second-order force components are known as mean drift forces. They are generally small in magnitude compared to their first-order counterparts, however, they may cause large excursions of the body from its mean position, in situations where there is a lack or very small hydrostatic restoring forces (Mavrakos, 1988).

So far, two principally different approaches have been presented in the literature for the determination of the mean drift forces. One is based on the application of the momentum conservation principle (Sclavounos, 1987; Molin, 1983; Mavrakos, 1995 to name a few), while the other is based on the direct pressure integration over the instantaneous wetted surface of the body. The latter method is applied herein, keeping all relevant terms up to second order. It has been introduced by Pinkester & VanOortmersen (1977), whereas Molin (1983) and Papanikolaou & Zaraphonotis (1987) extended the method by adding some missing terms regarding the vertical drift components and the pitch and roll drift moments. Other similar studies on mean drift forces using the direct integration method are Konispoliatis & Mavrakos (2014, 2021) and Konispoliatis et al. (2021).

EXAMINED CONFIGURATION

An array of N vertical, surface piercing and bottom fixed porous cylindrical bodies are examined consisting of an inner cylindrical impermeable column (see Figure 1). Viscous effects are neglected, and the fluid is assumed incompressible. A theoretical formulation is presented, which is suitable for solving the linearized diffraction problem around the array in the frequency domain. Specifically, the solution is based on the eigenfunction expansion method, in which analytical representations of the velocity potential are derived through the idealization of the flow field around each body. The condition on the porous boundary is defined by applying the Darcy's law, whereas the fluid velocity and its derivatives are matched at the common boundaries of adjacent fluid domains by enforcing appropriate continuity conditions. In addition, the interaction phenomena between the array's members are determined through the multiple scattering approach.

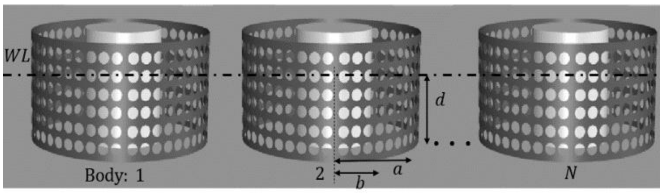

Figure 1. 3-D representation of the examined array of permeable cylindrical bodies

EXPRESSION FOR THE MEAN DRIFT FORCE

The drift forces are derived by the direct integration of the fluid pressure upon the instantaneous wetted surface of each porous body. Hence, for the bottom seated array-configuration, it holds:

$$\overline{F^2} = -\frac{1}{2}\rho g \int_{WL} \overline{\zeta_r^2} n dl + \frac{1}{2}\rho \iint_{S} \overline{|\nabla \Phi|^2} n dS$$

Here, ζ_r is the first-order relative wave elevation with respect to the transposed static water line WL of each body, S is the body's mean wetted surface, ρ and g denote the water density and the gravity acceleration, respectively, the term n is the unit normal vector pointing outwards of the body, and Φ is the velocity potential which describes the fluid flow around the array. The bars in the above equation denote the time average.

CONCLUSIONS

Numerical results are presented and discussed concerning the horizontal drift forces on the array. The main conclusions drawn from the study are that (a) the mean drift forces on the interior column shielded by the exterior porous shell can be reduced when compared to that without the exterior porous surface; (b) a no-flow condition at the porous surface can occur at certain wave frequencies, which enhances the wave impact upon the array.

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Ocean Thermal Energy Conversion (OTEC) Systems Prospect in the Mediterranean Sea

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INTRODUCTION

Renewable Energy systems (RES) related to the ocean and marine environment have seen a significant advancement in recent years, due to the promotion of such RES for the reduction of fossil fuels and CO2 emissions in general. Ocean Thermal Energy Conversion (OTEC) systems can be categorized as RES, as they exploit the stored solar thermal energy in the ocean surface.

METHODOLOGY

The natural temperature difference ΔT between the surface of the sea and the bottom, at great depths of about 1 km, gives rise to such exploitation potential. This capability can arise either for the generation of electricity or for the delivery of a by-product. The major disadvantage of OTEC systems lies in the availability and the location (i.e., distance from the equator), as the efficiency of the OTEC system depends on ΔT. A ΔT of over 20°C is recommended to provide a Carnot efficiency of 6.7%. OTEC systems aiming at the highest available ΔT, and hence a sufficiently high system efficiency, are suggested to be ideally placed in the tropical regions (or regions with ±20° from the Equator, including the Caribbean) where high ΔTs are recorded.

CASE STUDY AREA

The Mediterranean region (Sea), where OTEC systems could also be applied, tells another story (Soukissian et al., 2017). Compared to the Caribbean region, the sea surface temperature fluctuation is higher in the Mediterranean region (see Figure 1), with seasonal variation (i.e., winter or summer), with equally high mean values. However, the temperatures at the seabed in the Mediterranean are higher, by approximately 5°C, yielding a lower ΔT than tropical regions.

Estimation on the Mediterranean Sea temperature vertical profile in different sub-basins can be found in the literature (Carillo et al., 2012). Temperatures of 13°C at 1 km depths can be observed, with no significant changes for depths of up to 4 km, as can be seen in the sea temperature depth profile of Figure 1. The EU Copernicus Marine Environment Monitoring Service reports similar findings (through the recorded date). The rise of the sea surface temperature due to climate change, and the effect of the sources in the deep seawater, are aspects that researchers have considered and investigated (García-Monteiro et al., 2022; Sakalli, 2017).

RESULTS

It is a fact that the potential availability of the desired ΔT is evident in many locations worldwide, allowing for OTEC system installation for electricity generation. However, in the case of the Mediterranean Sea, based on an initial evaluation, one would suggest that it is not sufficient. The present scientific paper aims to investigate such potentials in the Mediterranean Sea, specifically in the south-eastern Mediterranean area in the island of Cyprus, with the aim to identify how these systems, namely the OTEC systems, could be viable in order, through their possible use, to contribute towards the EU climate emissions neutrality.

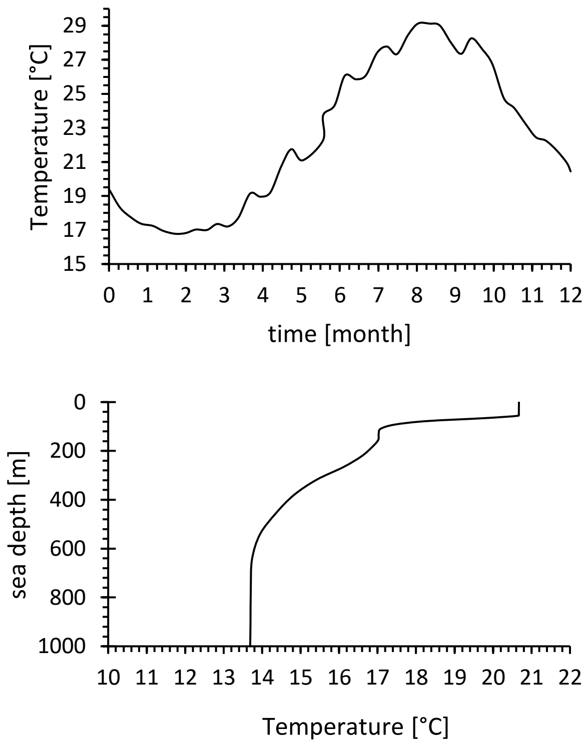

Figure 1. Surface sea temperature (top) and sea depth profile temperature (bottom) close to the Agia Napa Marina, Cyprus.

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Offshore Wind Farm – Design Basis – Site and Ecological Conditions: How to Reduce Risks and Optimize Design during Auction Process

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INTRODUCTION

During the early years 2000 of the offshore wind development, project developers were granted by the national authorities of a concession site for a duration of 20-25 years. The main drivers for selecting a project developer were the supporting subsidies for electricity production, the financial stability of the companies and the willingness to invest in such new technology. Since then, a lot of experience has been built within the offshore wind industry leading to a more technical and financial competitive approach. Government institutions have drawn auction plans for granting new offshore wind concession sites. Tender selection criteria are becoming crucial for granting new offshore wind concessions, these criteria consider technical, financial, and sustainable aspects.

In order to allow candidate bidders to prepare an optimal technical and financial bid, national authorities (such as Netherlands Enterprise Agency (RVO) in the Netherlands and Federal Public Service in Belgium) are collecting in advance the site conditions of next concession site, by coordinating offshore site investigations, desktop, and modelling studies. The Site Conditions for the Design Basis (DNVGL-SE-0073) and the Ecological Conditions to be collected regards mainly these categories:

- Desktop studies and data gap analysis
- Environmental conditions
- Wind and metocean conditions
- Soil data

The collected data are key for the candidate bidders to prepare their optimal tender design which will include offshore wind farm layout and LCOE calculations, basis of design for the WTG substructures, inter-array and export cables.

SITE AND ECOLOGICAL CONDITIONS

Desktop study and data gap

For the layout of an offshore windfarm, important information to be collected is the presence of seabed obstructions which will define a preliminary restriction zone (including a safety perimeter) for the layout of the OWF. These obstructions might be composed by third-party assets (i.e., cables, pipelines, platforms), presence of Unexploded Ordinance (UXO) or other natural (boulders…) or anthropogenic features (wrecks, chains, anchors…). During the mapping phase, a desktop study shall be performed for collecting information from public and private available databases. A data gap analysis and recommendations for the scope of works of field investigations shall be drafted as result of the desktop study.

As part of the study, an archaeological heritage and UXO desktop study should be performed. The aim of this study is to define risks and mitigating measures which could result in executing geophysical surveys, a combination of multibeam-echosounder (MBES), side-scan sonar (SSS) and magnetic (MAG) surveys, eventual underwater inspection and removal campaigns that will result in eventual As Low As Reasonably Practicable (ALARP) certificates for the execution of the works.

Environmental conditions

Environmental surveys are performed to determine the environmental baseline of the project area and the environmental impact of an offshore wind farm. These surveys are used as baseline for the Environmental Impact Study which results eventually on an environmental permit. Benthic, fish and shellfish, marine mammal and human / social impact studies are typically performed during the development phase of the project, depending on the specific relevance for the project site.

Wind and metocean

In order to determine the energy yield of the offshore windfarm and its optimal layout, and to understand the forces acting on the substructures of the wind turbines generators (WTG), monitoring of metocean parameters is performed by deploying floating Lidar, met-masts, metocean buoys and /or a combination of those. This monitoring campaign is followed by hydrodynamics numerical modelling studies. The output of the modelling studies results in statistical parameters (normal and extreme conditions) which are used to define hydrodynamics forces acting on WTG substructures.

Soil and seabed characterisation

The characterization of geology, geological properties, seabed morphology and morphodynamics is necessary to optimize the tender design of the WTG substructures and the subsea cables burial and protection strategies.

Geophysical (MBES, SSS, MAG and seismic surveys) and geotechnical investigations (vibrocores, CPT, boreholes, and lab testing sampling) are performed. These field investigations are accompanied by desktop / modelling studies to define geological conditions, ground model and geotechnical soil parameters, seabed morphodynamics studies and determination of Reference Seabed Levels (RSBL), scour assessment and natural seabed erosion…

CASE STUDIES

Case studies (protection of subsea power cables in the Belgian Part of the North Sea, seabed morphodynamics of sand dunes) will be presented to reinforce the importance of providing qualitative site conditions information to project developers.

CONCLUSION

This paper / presentation aims to prove the importance of collecting site conditions during the preparation of auction plans for offshore wind concessions. Within this context, national authorities and regulators play a key role for optimizing financial bids and technical solutions.

Offshore Wind: What is the Roadmap from Development to Construction?

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ABSTRACT

The deployment of offshore wind energy is at the core of delivering the energy and climate targets for 2030 and 2050. Offshore wind farm projects constitute large-scale constructions which pose a demanding technical and engineering challenge and require detailed planning several years in advance of the planned commissioning date.

The main phases of an offshore wind project are the development phase, pre-construction phase and construction phase. Each of them includes different kind of engineering studies, techno-economic analyses, and offshore works.

During the development phase, feasibility studies are carried out to ensure the viability and impact of the project as well as to support permitting process. Detailed design is taking place during pre-construction phase. Suppliers of the different components of a windfarm including offshore substations, wind turbines or cables are selected and financial closure of the project is performed. Construction phase is the final phase of the development of an offshore wind project and consists of the site preparation, transportation, installation and commissioning.

Required engineering studies and offshore works starting from the site investigation surveys to the final installation and commissioning works will be discussed in the present work. A roadmap from development to construction will be analysed and the key steps will be identified.

Multi-Criteria Cost-Benefit Analysis of Offshore Wind Farms in the Aegean Sea

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INTRODUCTION AND METHODOLOGY

Considering the globally scaled energy crisis, a holistic approach for minimal environmental impact exploitation of renewable energy sources on a country level appears to be a strategy towards energy security. The present paper deals with the topic of renewable energy sources, giving particular emphasis on offshore wind power and its technological implications. More specifically, the project for a sustainable life cycle of offshore wind turbine platforms in the Aegean Sea is thoroughly analyzed, examining both the environmental and the techno-economic components. The purpose of this work is to develop an integrated methodology in order to identify and evaluate the suitable areas for siting offshore wind farms in the Aegean Sea using multi-Criteria Analysis in combination with Geographic Information Systems (GIS). Similar work has been presented by Spyridopoulou et al. (2020) and Tsiarknias et al. (2022).

This paper goes a step further in examining the optimal sites for offshore wind farms in the Aegean Sea, taking into account criteria related to cost, location, depth, wind speed, legislative restrictions, environmental impact etc. The final product of this research comprises of a multi-layered map in ArcMap environment, that depicts the individual factors which have been considered and a value that corresponds to the performance of each specific site to each criterion. By this process, a fixed, gridded map of the Aegean Sea is produced. The aforementioned map correlates each site to a definitive score, based on every criterion that was taken into account.

In more detail, the methodology applied in MATLAB regarding the assessment of the life-cycle cost of an offshore wind farm comprises of six stages, all of which are related to the costs of each phase of the project. Specifically, these are concept definition, design and development, manufacturing, installation, exploitation and dismantling (Castro-Santos et al., 2016). The individual six costs are also coherent with each site's distance from shore, depth, wind speed etc. This method has been previously used to calculate the cost of a hybrid wind farm in three positions in the Aegean (Tsipouras et al., 2021); the latter work being a motivation for the present study.

The next stage of this work was to determine the exclusion areas, based on indicators related to legislation, social acceptance, environmentally sensitive areas and distance from the coast or from productive activities (Spyridonidou et al., 2020). Finally, the suitable areas are evaluated through the multi-Criteria Method.

The Weighted Linear Combination (WLC) approach was used for the multi-criteria site selection model. In this framework, each parameter is multiplied by a certain weight and the final results are summed using map algebra tools in order to obtain a definitive suitability index. The WLC method depends on the concatenation of the weighted averages of the selected parameters (criteria). Lastly, each parameter is characterized along with its weight distribution in GIS overlay layout.

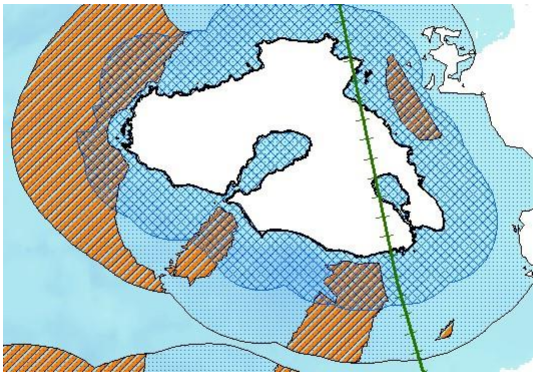

Figure 1. Indicative map excerpt for the region of Lesvos floating wind farm projects; (black outline: Greek coastline; orange hatch: Area suitable for corridor; blue grid: 6nm area; blue dots: 12nm area; shades of blue: bathymetry layer; green line: Main bird migration).

PRELIMINARY RESULTS AND CONCLUSIONS

The viable offshore options concerning location are considerably limited by the fact that exclusion areas due to legislative, environmental or land use factors are of substantial acreage. In that sense, strategic planning is of vital importance. Moreover, the development of synergies in a sense of multi-use areas seems crucial in terms of sustainable spatial planning as well as increasing social acceptance of offshore wind farms.

The results from the completion of this process agree to the fact that there are possibilities of exploiting offshore wind energy from the Aegean region, effectively contributing to the energy autonomy of the country. Clearly this research constitutes a macroscopic study of the optimal locations for a wind farm in the Aegean Sea, however the same framework could easily be applicable as a strategic spatial planning tool to a specific case-study, by recalibrating it in order to include the individual needs and characteristics of the site.

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A GIS-based MCDM Approach for Floating Offshore Wind Farms Site Selection in Greece

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INTRODUCTION

Switching to renewable energy currently seems the only way to tackle fossil fuel depletion, dependency on third countries for traditional energy sources and its associated geopolitical instability, as well as climate change. Offshore wind energy (OWE) has been identified as such source, capable to contribute to decarbonization, while achieving the United Nations Sustainable Development Goal (SDG) 7; Affordable and Clean Energy. Europe constitutes the global leader of OWE, with the European Council agreeing, in the context of "Fit-for-55" package, to set a binding target of 40% of energy from renewable sources in the overall energy mix, by 2030. However, OW power production capacity still needs further increase to achieve Europe's desired climate neutrality. Planning and optimal sitting of OWE are inherently embedded in the Marine Spatial Planning (MSP) process and explicitly mentioned in the the EU MSP Directive (2014/89). In Greece, despite the numerous scientific studies of OWE power plants site selection (e.g., Loukogeorgaki et al., 2018; Spyridonidou et al., 2020), currently no such plant has been deployed. Floating structures are the most promising alternative for deep seawaters found in Greece. Identifying the most suitable sites for OWE could be trivial, due to the number of parameters to be taken into account, including legislative, physical, technical and socio-economic restrictions (Tsarknias et al., 2022). MSP that considers the full spectrum of synergies and conflicts in the marine space could resolve the latter and provide robust results regarding site selection.

METHODS/TOOLS

Despite that most studies incorporate Geographic Information Systems (GIS) techniques and Multicriteria Decision Making (MCDM) approaches, they usually consider data anavailable online, as well as different exclusion and suitability criteria (EC and SC respectively), which lead to different areas selected for OWE farms' siting. Meanwhile, the spatial extent for which the analysis is performed affects the final result, hence the selected OWE sites. Only the best results at the national level are depicted, excluding options which could be of value at the regional level. To address these issues, in this research work, proper OWE locations are identified for the entire marine area of Greece by:

- Considering solely public open spatial data; Indicative sources of data are: EMODnet, Geodata.gov etc.
- Incorporating all necessary EC according to the country's legislative framework, the relevant literature review and potential conflicts with other marine uses (e.g., shipping and aquaculture);
- Investigating different scenarios regarding SC hierarchy and weighting and performing a sensitivity analysis in SC's weights for one of the scenarios.
- The effect of the analysis' spatial extent is investigated by further implementing the methodology at the regional level to allow for the identification of additional proper OWE locations.

The proposed methodology consists of four main steps:

1. The determination of the appropriate EC, which are then set as constraints (i.e., Boolean Maps).
2. The selection of the relevant SC, which are considered for selecting OWE farms' optimal siting. For these criteria, values between 0 and 1 are assigned through a standardization process (i.e., linear transformation).
3. The calculation of each SC's weight per scenario is conducted with the use of the Analytical Hierarchy Process (AHP; Saaty, 1977).
4. The evaluation of suitability areas (represented by cells in GIS environment) through the ranking of the final score (FS) of each cell. The latter is achieved via the calculation of additive weighting per cell. The weighted linear combination (WLC) or additive weighting is implemented in GIS environment, according to Eq. 1:

$$FS = \sum w_i x_i \cdot \prod c_i \qquad (1)$$

where, FS is the final score of each cell; w_i and x_i stand for the weights and the corresponding SC, respectively, and c_i represents the EC. This formula results in values ranging from FS=0 in cases where at least one EC is identified, to FS≤1, denoting the cells which represent suitable locations.

RESULTS/CONCLUSIONS

Various scenarios of OWE farms siting are tested, through the assignment of different weights among the selected SC. In order to investigate the effect of weight alterations (w_i in Eq.1) and to strengthen the robustness of the results, indicative suitability maps of optimal sites are presented at the national level, based on a sensitivity analysis for one selected scenario, as well as further proposed locations at the regional level.

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Greek Port Infrastructures Assessment towards Floating Offshore Wind Farms Development

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INTRODUCTION

Ports have a prominent role for developing Floating Offshore Wind Farms (FOWFs) and, thus, exploiting offshore wind energy in deep waters. As the interface between land and sea, they can provide sufficient infrastructure and services during the various FOWFs lifecycle phases (from storage and pre-assembly to O&M) and support efficiently the relevant local supply chain and logistics, contributing to costs reduction (Wind Europe, 2020). However, the aforementioned abilities require significant investments for ports to upgrade and expand their infrastructures, including diversification of their operations to support ever-increasing demands. In the present paper, we assess six large and important ports in Greece (Piraeus, Thessaloniki, Alexandroupoli, Patra Volos, and Heraklion ports) in terms of their suitability to support the development of FOWFs in the country.

METHODOLOGY

For assessing the examined Greek ports, specific suitability criteria, adopted from existing FOWF, mainly in northern Europe, are considered. Those criteria are grouped into three different categories (Table 1) corresponding to port's physical characteristics, connectivity and layout (Akbari et al., 2017). For each criterion, a minimum requirement is assigned and the suitability of the ports is assessed based on the number of criteria satisfied in terms of the aforementioned requirements. The assessment is implemented for three different scenarios (SC) by modifying the manufacturing location of the floating platform. In SC1, the platform is manufactured abroad and it is transported to the port of interest, while in SC2, it is manufactured at the examined port's facilities. Finally, in SC3, the platform is manufactured at Greek shipyards and it is, then, transported to the port.

Table 1. Port's suitability criteria

Port's physical characteristics	Port's connectivity	Port's layout
Entrance's depth & width	Road and railway network connection	Storage space & workspace
Number of adequate quays	Proximity to steel production units	Parts handling equipment
Quay loadbearing capacity	Proximity to concrete production units	Construction area (shipyards)
Quay length & depth		Office facilities

ILLUSTRATIVE RESULTS

Having collected all required data for the examined six ports, their suitability to support the development of FOWFs in the Greek marine environment is assessed for all three scenarios. In the case of Piraeus port, the minimum requirements of most of the criteria are met due to its increased commercial activity (Table 2). However, all other ports seem not to have the required ability to offer their infrastructures for supporting the various FOWFs lifecycle phases. This is mainly attributed to the absence of adequate water depth, sufficient workspace area and equipment necessary for the various processes. The absence of shipbuilding dry docks in all ports except of Piraeus presents also an important drawback.

Table 2. Indicative SC2 assessment results for Piraeus port (Y=Yes, N=No)

Port's physical characteristics		Port's connectivity		Port's layout	
Adequate entrance's depth (>12 m) & width (>135 m)	Y	Road and railway network connection	Y	Sufficient storage space & workspace	N
Number of adequate quays (min 3)	Y	Proximity to steel production units	Y	Available equipment	N
Quay length (min 200 m)	Y	Proximity to concrete production units	Y	Construction area (shipyards)	Y

MAIN CONCLUSIONS

The results of the present paper indicate that none of the examined six Greek ports in its current form is suitable to support efficiently all the processes required for the construction and operation of an FOWF. Accordingly, upgrading of existing port infrastructures is required, including mainly dredging activities to increase water depths and ports supply with the necessary equipment. The construction of shipbuilding dry docks, as an upgrade measure, has a high cost and can change the commercial activities of the port. Choosing to build new suitable port facilities is another solution that requires a careful spatial study accounting for interconnections with industrial centres in the mainland. Overall, investments should be directed towards the strengthening and expansion of ports to support the development of FOWFs in Greece.

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Harvesting Offshore Wind Energy for Climate-neutral Hydrogen Production

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INTRODUCTION

The extensive intrusion of renewable energy sources in the total energy consumption is considered nowadays necessary for decongesting the planet from greenhouse gas emissions. For this reason, new technologies, such as climate-neutral hydrogen production, are promoted. Hydrogen is a flexible product and can be used to achieve high temperatures through its combustion, even as a raw material in the primary sector (European Commission, 2020). Moreover, the greatest feature of hydrogen is its storage capacity.

Motivated by this, the present paper focuses on the production of climate-neutral, green, hydrogen through water electrolysis by harvesting the vast offshore wind energy. The proposed process involves the deployment of Offshore Wind Turbines (OWTs) to produce the electricity required for the desalination of the seawater and for its subsequent electrolysis, enabling the production of hydrogen with no greenhouse gas emissions. A methodology is developed, where the produced amount of climate-neutral hydrogen and the weighted cost of its production are calculated for a given, available for this purpose, capacity of installed Offshore Wind Farms (OWFs). Finally, the hydrogen produced is distributed and used in the industrial and transport sectors.

METHODOLOGY

The developed in the present paper methodology consists of of three phases and aims at calculating the produced amount of climate-neutral hydrogen (tn) along with the Total Levelized Cost (TLC) of its production (€/kwh) for a given capacity of OWFs. TLC is quantified as follows:

$$TLC = LCoE + LCoDS + LCoH \quad (1)$$

where $LCoE$, $LCoDS$ and $LCoH$ are the levelized costs of energy (i.e., the electricity produced by the OWFs), seawater desalination and hydrogen respectively.

In the 1st phase of the proposed methodology, we use the System Advisor Model (SAM) software to estimate the electricity produced by one or more OWFs and the corresponding $LCoE$ (Eq. 1). OWFs of specific characteristics (number of OWTs, type of support structures, capacity per OWT etc.), installed at given marine locations are taken into account. The 2nd phase focuses on the desalination process of the seawater, which is realized by deploying the Mechanical Vapor Compression (MVC) method, and the quantification of $LCoDS$ (Eq. 1). Finally, the 3rd phase deals with the electrolysis of the pure water, which is based on the Proton Exchange Membrane ELectrolysis (PEMEL) method, and it includes the calculation of the produced hydrogen and of the $LCoH$ (Eq. 1).

ILLUSTRATIVE RESULTS

The methodology described above is applied for an available for climate-neutral hydrogen production capacity of 2 GW. This capacity results from floating OWFs installed in the Greek marine environment. The locations of the OWFs (Figure 1) have been selected based on Spyridonidou et al. (2020) by giving emphasis on siting criteria related to the average water depth and the wind speed 50 m above the mean water level. The available 2 GW are distributed to all possible locations, with maximum coverage area of 40% (Case 1) and 75% (Case 2) per location. The corresponding results for these two portfolio cases are shown in Table 1. It is mentioned that for calculating the total amount of produced hydrogen, losses from all the various processes (2nd and 3rd phases) have been taken into account. Finally, for both cases, we highlight the electricity demands that can be covered in the Greek industrial and transport sectors by the produced hydrogen, as well as its potential use as an e-fuel.

Figure 1. Location areas of floating OWFs considered herein

Table 1. Illustrative results for the two examined portfolio cases

Quantity	Case 1	Case 2
OWFs produced electricity (TWh)	3.4	3.8
Produced hydrogen (tn)	63707.4	70317.3
Energy carried by hydrogen (TWh)	2.124	2.344
Available electricity from hydrogen conversion considering losses (TWh)	1.359	1,524
$\boldsymbol{TLC}$ (€/kwh)	0.256	0.245

CONCLUSIONS

The results of the present work indicate that there are quite large losses when converting electricity into hydrogen, and backwards, while the cost of producing green hydrogen from offshore wind is high. So, there are still challenges that have to be addressed to come up with cost-efficient hydrogen production solutions. The exploitation of the hydrogen's storage ability may be considered as a driver for "balancing" these challenges.

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Investigating the Potential of New Marine Protected Areas in the Greek Marine Territory

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In recent years, there has been considerable debate about the ongoing geopolitical and economic development in the Eastern Mediterranean. Efforts are being made by the Greek Administration to extend its coastal zone to 12 nautical miles (n.m.) and to designate country's Exclusive Economic Zone (EEZ) with neighboring states. Also, discussions are taking place on how Greek Administration can exploit EEZ for the unitization of energy resources while protecting its unique marine environment. There are numerous criteria (social, economic, environmental, geopolitical, etc.) based *upon* which a Member State within EU may decide whether to allow the establishment of economic activities in the marine space and at the same time to ensure the protection of the marine environment. In 2021, the Prime Minister of Greece addressing the general assembly of IUCN conference in Marseille stated that Greece will not allow fishing in 10% of its seas, with the aim of better protecting and stimulating the ecosystems of the Mediterranean, which has been affected by overfishing. Having the political willingness of a Nation expressed in such high level, the motivation to explore possible planning options is very strong. So, in this paper, an analysis based on this commitment is developed to identify new marine protected areas (MPAs) within the Greek marine territory.

According to Reuchlin-Hugenholtz and McKenzie, (2015) a Marine Protected Area (MPA) is defined as an area dedicated for the protection of marine habitats, fauna and flora species and their functions. These functions are critical, because they significantly contribute to the restoration and recovery of natural environment affecting not only environmental but also economic, social and cultural aspects of people's life. Furthermore, MPAs are delimited within the national territorial waters ('territorial sea') of each country. The classification of MPAs is similar to that of terrestrial protected areas. As a consequence of the European Union (EU) decision to increase the arial coverage of protected areas in Europe to 30% of its sea area by 2030, Greece has decided to define new protected areas in order to achieve this goal (EEA, 2022).

Figure 1. Potential new MPAs within Greek Marine Territory (conservative (left) and realistic (right) scenarios.

The purpose of this analysis is mainly to designate new MPAs by developing alternative scenarios and to analyze how geopolitical conditions in the Easter Mediterranean basin may contribute to the determination of them. Essentially, an attempt was made to strengthen the willingness of Greece to establish the 12 n.m. border line at the sea through certain geopolitical hypotheses related to the designation of new MPAs.

To achieve this objective, an analysis of the fundamental issues - associated with EEZs, continental shelf, the current treaties concerning EEZs between Greece and foreign states involved and the current situation with the foreign states with which no final agreement has been reached - is performed, pointing out the importance of maritime spatial planning. Then, the current environmental legislation for the protection of the marine environment is analyzed and a prioritization of endangered species is carried out. The prioritization of the marine fauna species detected in Greek marine territory was accomplished by the IUNC criteria, the classification of species in the annexes (II and III) of Directive 92/43/EEC and the Barcelona Protocol. Based on this preparatory analysis, three scenarios (conservative, realistic and optimistic) for the determination of the new MPAs extending up to 12 n.m. were developed considering environmental and geopolitical criteria.

		EEZ (km^2)	Territorial Zone (km^2)
	Area (km^2)	482.910	184.446
Conservative	11.255,33	2,33%	6,10%
Realistic	22.923,90	4,75	12,43%
Optimistic	122.052,2	25,27%	66,17%
Existing Natura 2000 sites	39.214	8,12%	21,26%

Table 1. MPAs coverage based on the examined scenarios.

The outcomes of the analysis summing up the existing Natura 2000 coverage (21.26%) in the Greek sea show that, even with the most conservative scenario, the 30% goal could be achieved. Whereas the goal is overachieved for the realistic (33.69%) and the optimistic (87.43%) scenarios (Figure 1). In addition, the optimistic scenario recommends a strict protection zone covering more than 50% of the 12 nm of Greece's territorial zone (Table 1).

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Assessing Coastal and Port Vulnerability through a Single Composite Index to Support MSP

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INTRODUCTION

Coastal areas lie at the land-sea interface where heterogeneous social settlements can be found, from coastal megalopolises to low-density areas with scattered communities. These areas host not only more than one-third of the total human population, but also a variety of human activities and crucial infrastructure, including ports. The growing activity of humans in the sea has generated competing demands for ocean marine space, which challenge established institutional governance arrangements. As a result, marine spatial planning (MSP) emerged as a policy framework to optimize marine space allocation, avoid negative interactions, improve synergies, and advance toward a sustainable ocean economy, as reflected in explicit mandates for MSP, such as the EU MSP Directive (2014/89). Despite the fact that MSP usually focuses on large marine areas (from coastal to open-ocean regions), whereas coastal zone management tends to be more focused on the coastal zone (Kerr et al., 2014), there is currently a strong emphasis on the incorporation of land-sea interactions into the MSP process. The reason could be twofold: i) MSP is required by an already established policy framework, at least for Europe and ii) coastal zone is a narrow, yet vital part of the ocean, where numerous human activities are undertaken and affect the entire marine space. However, both coastal areas themselves, coastal communities and critical port infrastructure are threatened by climate change and its associated impacts. Coastal zone has been identified as a vulnerable area, affected by sea level rise, storm surges and flooding related to climate change. Therefore, assessing vulnerability of the coastal zone in a holistic, rather than sectorial manner, seems to be the first step of MSP initiatives that actually contribute to minimize climate impacts.

ASSESSING VULNERABILITY OF THE COASTAL ZONE: DEFINING THE GAPS

Vulnerability definitions are numerous and mainly express the risks to different elements of natural and man-made environment by various sources, among them climate change (Kontogianni et al., 2019). When comparing vulnerability of multiple disparate systems, indicator-based vulnerability assessment methods can yield standardized metrics, allowing for both the proper identification of areas or systems of concern (McIntosh and Becker, 2019) and the development of targeted adaptation interventions.

Traditionally, the vulnerability of the coastal zone is studied through the Coastal Vulnerability Index (CVI), mainly focused on physical, geomorphological and geometrical parameters of the area. On the other hand, port infrastructure and its functions are studied as a separate system through Port Vulnerability Index (PVI). These indices incorporate different indicators and usually fail to consider the interactions between the coastal system and critical infrastructure, let alone the communities and the other human activities undertaken in the coastal zone, such as fisheries and aquaculture. Integrated vulnerability approaches and composite indices could be used to inform MSP scenarios and visioning processes.

COASTAL AND PORT VULNERABILITY ASSESSMENT FRAMEWORK FOR MSP

To address the sectorial approach of vulnerability assessment in the coastal zone, we hereto propose a 6-step framework that takes into account the multiple activities and infrastructure of coastal areas, along with their interdependencies and climate change, to inform MSP. The proposed steps are set as follows:

1. Selecting the area of interest; definition of geographical boundaries.
2. Mapping of existing conditions; identification of physical conditions, existing port infrastructure, human population dynamics, human activities and interdependencies.
3. Developing a comprehensive and composite vulnerability index (VIcomp); selection of appropriate indicators that describe potential vulnerability of natural assets, ports and other critical infrastructure, humans and human activities in the coastal zone.
4. Evaluating indicators to determine current vulnerability; data collection that allows for indicators' quantification and assignment of values to each indicator selected.
5. Considering climate change and its impacts; re-evaluation of indicators based on climate change projections, when available, or on perception of the climate change impacts on assets.
6. Using vulnerability assessment to support MSP; comparison of current and future vulnerability index and identification of the most vulnerable assets/areas to inform a dynamic, climate-related MSP process.

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Spatial Delimitation of the Coastal Zone in the Context of Evaluating Environmental Impacts of Artificial Constructions

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INTRODUCTION

The coastal zone is the area where most human activities (tourism, fishing, aquaculture, maritime transport, ports, agriculture and industry) take place, exhibiting significant economic development. It is estimated that over 200 million of the European population (680 million in total) are concentrated within 50 km of the coastline. In the meantime, coastal zones are highly dynamic and changing systems, both in space and time, in response to factors such as hydrodynamic and sedimentological activity. However, although the term 'coastal zone' is generally comprehensible, there is no common definition of what exactly constitutes a 'coastal zone', but rather several complementary definitions, each serving a different purpose, occasionally using arbitrary criteria. The objective of this study is to carry out an analysis of the various approaches to defining the coastal zone, considering institutional, operational, social and physio-geographic characteristics.

METHODOLOGICAL APPROACH

The definition of the coastal zone calls for a comparative analysis of the specific coastal management laws, national legislation, and thorough understanding of the natural environment. Methodologically, an integrated approach to the coastal area should consider the following aspects:

- The analysis of the institutional framework
- The evaluation of the applicable regulatory instruments
- The criteria used to determine the geographical area
- The operative (land use, socio-economic) criteria

RESULTS & DISCUSSION

Figure 1 summarizes the boundaries of the coastal zone considered in the present analysis, as defined in the diverse institutional, legislative, management and physio-geographic contexts:

- The institutional context, as introduced by the United Nations Convention on the Law of the Sea (UNCLOS, 1982)
- The European legislative framework relevant to the coastal zone, such as the Habitat Directive (92/43/EC), Water Framework Directive (2000/60/EC), Marine Strategy Framework Directive (2008/56/EC), Maritime Spatial Planning Directive (2014/89/EU).
- The national legislative regime and specificities, such as law L.2971/2001 in the case of Greece.
- The management context, as introduced by the Integrated Coastal Zone Management Protocol of the Barcelona Convention (Art.8, §7).
- The physiogeographic context, as defined by the prevailing morphological, hydrodynamic and morphodynamic regime.

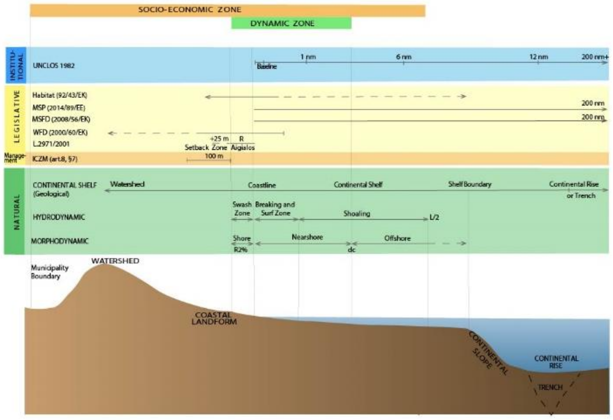

Figure 1. Definition of the Coastal Zone in the diverse contexts.

Besides the inherent difficulty, establishing criteria for the definition of the coastal zone area can be viewed as a challenge as it entails flexibility in its application depending on the raised definition requirements. In short, in physicogeographic terms the critical beach front (differentiated by the coastal zone to which it spatially belongs to) is defined based on the morphodynamic characteristics as following: Towards the sea it extends to the maximum depth of the mobilization of bottom sediments (closure depth) during which the interaction of waves and bottom surface is particularly intense. Landward, the active beach front includes the whole coastal landform and is delimited by the (natural or artificial) characteristics of the backshore zone (cliff, sand dune, infrastructure, etc.).

In the context of management, the boundary of the coastal zone seawards may be set at 50m depth, where the majority of activities and uses are concentrated. Landwards, setting the coastal zone boundary requires the consideration of relative legislation, so as to, amongst other reasons, prevent environmental degradation caused by human activities and protect from the effects of human intervention (erosion). Hence, the economic effects of erosion, along with the construction costs of the necessary infrastructure to alleviate its impacts, necessitate social and economic data to inform the definition of the coastal zone. Depending on their availability, the economic evaluation, in a national level, may be based on nearshore property values information or may rely on data with respect to the entire municipal unit, thus considerably extending the notion of the coastal zone.

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Design of Coastal Aquaculture Structures and Allocated Zones for Aquaculture Development in Cyprus

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INTRODUCTION

Aquaculture requires the use of extensive marine space and coastal infrastructure hence competing for space with activities such as tourism, fisheries, marine navigation, energy, recreational and other coastal activities. Although open sea aquaculture alleviates space constrains, its wide use is hindered by the availability of robust fish cage and mooring systems, able to withstand open sea conditions. The Open Sea Aquaculture in the Eastern Mediterranean (OS Aqua) Project, co-financed by the European Regional Development Fund and the Republic of Cyprus through the Research and Innovation Foundation (Grant No. INTEGRATED/0918/0046), will enable the strategic development of an open sea aquaculture industry in Cyprus. The project takes a multidisciplinary approach to minimize environmental impact and resolve socioeconomic constrains. Here we present the results of the maritime zone definition and design of open sea cage system.

SCOPE

Among other activities, the project produced a Marine Spatial Planning study (MSP) specific to OS aquaculture development in Cyprus and a cage system with its associated mooring system.

MARINE SPATIAL PLANNING (MSP)

To determine suitable areas for the establishment of the Allocated Zones for Aquaculture (AZAs), a MSP methodology implemented in three phases:

1. Application of exclusion criteria to define the available maritime space.
2. Application of proximity and weather conditions criteria to define a series of more specific candidate OS AZAs.
3. Selection of the optimal candidate areas for further investigation by taking into consideration the opinions of relevant stakeholders and partners.

The geographical data used for this study include data form sources such as the Department of Land and Surveys (DLS), Ministry of Interior, the cartographical database of T.C. Geomatic Ltd, Geomatic Maps™ (Geomatic), and Department of Environment, Ministry of Agriculture, Rural Development and Environment (DoE).

The outcome of the MSP was the selection of four (4) candidate areas suitable for the establishment of Allocated Zones for Aquaculture (AZAs), and Aquaculture Management Areas (AMAs) within an AZA: Xylofagou West, Larnaka, Governor's Beach Center East and Aphrodite Hills.

RIGID-TYPE FISH CAGE SYSTEM DEVELOPMENT

A steel semi-submersible rigid fish cage system with multiple draughts adequate to withstand maximum significant wave height of 8 meters was conceptualized during this project. Two to four rectangular or circular cages of breadth 10 or 20 meters may be installed in each of the two compartments. The two pontoons maintain provisions for ballasting and deballasting (appropriate valves and submersible electric pumps) in order to adjust the structure's draught. Each pontoon hull is divided in three watertight compartments for enhanced survivability. The top platform provides access to the perimeter of the structure and could be used to attach Photovoltaic or other Renewable energy systems. Mooring points for supporting vessels are provided perimetrically on the top platform. Towing points are fitted on the pontoons. A hydraulic crane of radius of 27 meters is provided on the port side serving the structures over the side and able to reach any combination of cages. On the top platform, in way of the mid passageway, a deckhouse is installed consisting of diesel generator compartment, including a separate fuel tank, and feed storage compartment, which may also include feeding equipment machinery. The structure can have various operational draughts so that it can withstand large waves in heavy weather. Every individual structure can be anchored with either an eight point mooring system or single point mooring, depending on chosen area (available surface) and number of structures that will be required for a complete fish cage system.

Figure 1. Rendering of the OS-Aqua cage system design

Incorrect Natura 2000 Habitats and Spatial Extent of Protected Species in the Case of Coastal Zone of Kyparissiakos Gulf, Greece

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INTRODUCTION

In the coastal area of the Kyparissiakos Gulf they have been delimited three protected areas of the NATURA 2000 Network; two terrestrial coastal areas (GR2330005 (Marine area of Kyparissia Bay: Akr. Katakolo - Kyparissia"), GR2550005 (Kyparissia Dunes (Neochori - Kyparissia) and one marine area (GR2330008 (Kyparissia Bay Marine Area: Akr. Katakolo – Kyparissia). The aforementioned 3 protected areas include a total of 37 priority habitats and 4 protected species.
The aim of the paper is to highlight the incorrect use of certain habitats in the configuration of the NATURA 2000 (European Union) sites, as well as the incorrect spatial reference of certain protected species, which result in the hindrance of the economic development of the area.

METHODOLOGY

For the implementation of this research action the following data were collected and subsequently evaluated: (i) the Standard Data Forms (SDF 12/1994) of the Natura 2000 site GR2330005, SDF 04/1995 of the site GR2330008 and SDF 04/1995 of the site GR2550005; (ii) the Special Environmental Study entitled "Special Environmental Study (SEIS) of NATURA 2000 Protected Areas a) GR2330005: Dunes and coastal forest of Zacharo, Lake Caiafa, Strofylia, Kakovatos and b) GR2330008: Marine area of Kyparissia Bay: Akr. (NERCO - N. Hlykas & Co: "E.P.M. of NATURA 2000 Protected Areas: A) SPA (GR2550005) "Kyparissia dunes (Neochori - Kyparrisia)" and B) SPA (GR2330008) "Marine area of Kyparissia bay: Akr. Katakolo - Kyparissia" (NERCO - N. Hlykas & Co; (iii): SPANOU, S. (2001) Mapping and detailed description of the habitats of the area GR2330005: Dunes and coastal forest of Zacharo, Lake Kaiafa, Strofylia, Kakovatos. (iv) The final project report: OPER - Sub-programme 3 - Measure 3.3. - 'Identification and description of habitat types in areas of interest for nature conservation. Study 2, Scientific Officer Georgiadis Th. Ministry of Environment, 1999-2001; and (v) The study SPANOU, S. (2001): Mapping and detailed description of habitats in the area GR2550005: Kyparissia dunes. Final project report: OPER - Sub-programme 3 - Measure 3.3. - 'Identification and description of habitat types in areas of interest for nature conservation. Study 2, Scientific Officer Georgiadis Th. TRANSHUMANCE, 1999-2001

RESULTS AND DISCUSSION

The survey shows that the habitat 1110 (sandbanks), which does not exist in the Kyparissiakos Gulf nearshore area, has been incorrectly included in the SDF of the site GR2330008 (Natura 2000 priority habitat list); the mistake is due to the fact that as sandbanks have been taken the existing nearshore bars whose presence, location and morphology depend on the changing hydrodynamic conditions during wave breaking. Also, habitat 1120 (Seabed areas with seagrass vegetation) with a declared coverage of 80% (SDF 1995), has proved to have an actual coverage of about 0.3% being limited exclusively to the northern and southern end (reef) of the Gulf (NERCO 2014). Also, area GR2330005 and the central and northern part of area GR2330008 (about 64 km of sandy coast) are incorrectly listed as important habitat for the protected specie 1224 (Caretta caretta), whose main nesting sites being limited exclusively to the southernmost part of the Kyparissiakos Gulf. More specifically, nets are present within a coastal sector of about 11 km, extending from the mouth area of the Neda River and southwards. To the north of the Neda mouth beach zone presents from 0 to <5 nests/km/season. Moreover, the two existing habitats of the NATURA site GR2330008 (Posidonia and reefs) have a cumulative coverage of only <1% of its total area (11. 324,62 ha). It is also regarded as misleading the inclusion in the two Special Environmental Studies (NERCO 2011 and 2014) 2 habitats (119A & 119B) from the National List (not of the NATOURA network) with a total coverage of 55,4%, although in the same works was stated that "they are not of importance and their conservation is not considered necessary".

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A Shipping Commitment against Plastic Pollution in the Mediterranean: Action Plan for Harbors

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INTRODUCTION

The Cyprus shipping sector is the 3rd largest in Europe and the 11th largest in the world. About 270 shipping companies are based in Cyprus and the industry contributes ~7% to Cyprus's GDP.

The Cyprus Shipping Strategy, issued by the Cyprus Shipping Deputy Ministry (DMS), aims for "Cyprus to be a significant and influential actor leading positive change in global shipping and an attractive maritime centre striving for sustainable growth and excellence" (Shipping Deputy Ministry, 2021). In addition to its carbon emissions, the global shipping industry must strive to address the issue of marine litter. This is particularly important in the Mediterranean, which has been identified as the most polluted sea in the world where 20%-30% of marine litter comes from sea-based sources, and where over 80% of litter is plastic (Fossi et al., 2018).

ISOTECH, with support from the BeMed Foundation (www.beyondplasticmed.org), worked with Cypriot shipping industry stakeholders, including policy-makers and port reception facilities, to identify practices that are implemented by the industry to minimize plastic waste, and to set the industry's Action Plan for plastic waste minimization and waste management optimization. Creating fit-for-purpose port infrastructure and port reception facilities is a key pillar of the resulting Action Plan.

METHOD

To develop the Action Plan, ISOTECH implemented its participatory decision support method, DeCyDe-4 (Loizidou et al., 2021), which was adopted to meet the needs of the work by creating the specific DeCyDe-4-Shipping method. The method involved stakeholder mapping to identify all key actors across the Cypriot shipping industry value chain, including policy makers, port reception facilities, ship owners and managers, consultants, academia, and NGOs. The stakeholders participated in a Policy making workshop, through which they were guided, using the DeCyDe-4-Shipping method and tools, to the identification of the major gaps/needs that the industry faces with regards to waste management, and the prioritization of actions to be implemented for plastic waste minimization and waste management optimization. Practices already implemented have been identified. Actions were categorized across four major pillars: A. Infrastructure: Creating fit-for-purpose Port Reception Facilities; B. Policy Implementation and Enforcement; C. Research and Innovation; and D. Environmental Behaviour and Awareness Raising. This paper focuses on the Actions in Pillar A.

RESULTS

A key gap/need emerging from the participatory stakeholder engagement is that better infrastructure is needed at port reception facilities. To address this need, the stakeholders agreed that emphasis should be placed on better separation and delivery of waste, and the implementation of schemes that would reward and incentivise best performers that minimise and properly separate their waste. A four-point Action Plan was agreed among the stakeholders for ensuring that fit-for purpose infrastructure will be developed in Cyprus Harbors (Table 2). The Action Plan defines the organizations that must be involved for the implementation of each action.

Table 2. The 2022-2023 Action Plan for Pillar A: Creating fit-for-purpose Port Reception Facilities

Pillar Category	Action	Organizations Involved
A1. Define waste categories and identify suitable and authorized waste handlers	Emphasis should be placed on identifying licensed contractors that utilize the waste they collect according to the principles of the circular economy	Cyprus Shipping Deputy Ministry, Cyprus Port Authority, Privately managed port terminals, Individual shipping companies
A2. Develop necessary infrastructure	Following on from measure A1, additional infrastructure must be developed to ensure that the waste is properly segregated in a way that facilitates its collection and valorization	Cyprus Shipping Deputy Ministry, Cyprus Port Authority, Privately managed port terminals, Individual shipping companies
A3. Revise fees to incentivize waste minimisation	Clarify the provisions of Cypriot law that allows reduced fees to vessels that implement waste minimization measures. This will ensure that vessels are aware of what proof is required by the Cyprus Port Authority.	Cyprus Shipping Deputy Ministry, Cyprus Port Authority
A4. Transform Cyprus ports into pioneering circular ports	The Circular Economy must become part of the strategy and operations of ports, setting Cypriot ports ahead of the competition.	Cyprus Shipping Deputy Ministry, Cyprus Port Authority, Privately managed port terminals, Expert consultants

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Circular Economy: Re-Use of Building Materials at an Island's Port Project

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INTRODUCTION

During the transition from linear economy to "circular economy", referring to a production and consumption model that aims to increase the efficiency of raw materials through the use of materials for a longer period of time, it is necessary to re-use building materials whenever possible, especially preserving the limited natural resources of the Greek islands.

LEGAL FRAMEWORK

The Joint Ministerial Decision No. 36259/1757/E103/2010 Official Gazette 1312/B/24-8-2010 describes "Measures, conditions and programming for the alternative management of waste from excavations, constructions and demolitions (AEKK)". The accounting costs of a construction project include the A.E.K.K. reception fee (asphalt, stones, soils, gravel, lightly reinforced concrete, etc.).

But that does not account for the environmental cost… especially when it refers to the limited area islands where every consequence is magnified, being difficult to reverse.

INITIAL DESIGN OF A TOURIST SHELTER

In 2002, EOT's technical services design a tourist boats' shelter, at Xylokeratidi, Katapola Bay, Amorgos Island. During the construction phase, embankment materials had been gathered and several solid and cellular artificial blocks were constructed.

The project was canceled due to legal decisions (STE) thus the embankment materials and the artificial blocks were "temporarily" deposited on Katapola beach, forming a whole new pier on the coast, splitting the beach in two parts, causing visual and environmental damage, as well as strong reactions from swimmers, locals and visitors affected.

In total, the quantities that had been deposited forming the new 1,780 m^2 area pier on the beach of Katapola bay, were: 3,000 m^3 of embankment materials, 12 solid blocks (2.0m x 3.0m x 1.5m = 12 x 9.0 m^3 =108.0 m^3) and 5 cellular blocks (4.0m x 7.0m x 1.3m = 5 x 36.4 m^3 =182.0 m^3).

NEWER DESIGN OF THE FISHING SHELTER

During the new study of the fishing shelter at the same location, a different design was applied well coinciding with the bathymetry and the surrounding environment, also providing a full berth servicing a patrol ship.

Provision was taken to use and integrate all the materials and blocks from the previous contract in the new project, saving resources and materials, while in parallel the Katapola bay beach has been freed and finally restored to its original shape. It should be noted that the re-use of the 5 big cellular blocks of large dimensions and weight, was very challenging.

Finally, during the construction of the new fishing shelter at Xilokeratidi, the 5 cellular blocks -weighing 68.22 tons each- were used to form the head of the breakwater, while the solid blocks, weighing 21.60 tons each, were incorporated into the construction of the shelter's docks.

Also, the whole of the embankment material was used into the new construction, reshaping the beach of Katapola given over to the swimmers, reducing the cost of the shelter as well.

After the completion of the fishing shelter, the Katapola beach had returned to its original state, as shown below (summer 2021), welcoming the swimmers. The decades old, requested project, was recently awarded on the "Recreational projects" category of the Best City Awards 2023, KEDE.

Figure 1. Katapola beach (2015) shortened by the pier consisted of embankment material and 17 concrete blocks.

Figure 2. Katapola beach (2021) has been fully restored.

Figure 3 & 4. Satellite photos of Katapola bay before (3) and after (4) the construction of the fishing shelter (on the left).

CONCLUSION

Circular economy should be a key objective of the islands and island regions development, contributing to the achievement of a balanced development that will make the islands sustainable for all days of the year, despite their particularities. Thus, it is considered necessary during the construction of major works to attempt reducing the environmental footprint through the minimization of waste and the reuse of the limited natural materials.

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Sea Bottom Evolution Considering Wave Events Sequences and Environmental Aspects: the Case Study of Kolymvari Coast, Crete

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ABSTRACT

In the present study, a numerical investigation of sea bottom evolution of the Kolymvari coastal zone is performed, which is accomplished by using the methodology of wave events sequences. The adopted approach accelerates remarkably the simulation of long-term coastal morphodynamics, and estimates with satisfactory accuracy the coastal evolution as a function of time. Moreover, coastal processes are simulated under the presence of coastal structures aiming to protect the coast from erosion and extreme wave conditions without degrading significantly the suitable nesting habitat of sea turtles.

INTRODUCTION

The short- and long-term coastal evolution is usually investigated through process-based morphodynamic models. However, the models' complexity and the inherent high computational cost, especially regarding long-term analysis, necessitate the development and implementation of wave input reduction and acceleration techniques (Benedet et al. 2016). Although these acceleration techniques, e.g. the Energy Flux Method or the Sediment Transport Bins Method, are widely used in coastal engineering studies, they do not consider, in detail, wave chronology to predict the sea bottom and shoreline evolution, and, thus, are somehow inadequate for coastal zone monitoring. In the present work, the coastal zone evolution is estimated as a function of time, e.g. before and after extreme coastal storm events that can induce severe sea bottom changes. Furthermore, the effectiveness of the construction of four new breakwaters is checked in order to ensure the coast's resistance and ecological value.

STUDY AREA

The area of interest is the sandy coast of Kolymvari, located on the northwest coast of Crete Island, S. Greece. In the present situation, three emerged rubble mound breakwaters, were constructed in 2020, based on an experimental study performed in the Laboratory of Harbor Works (National Technical University of Athens). In the current study, the coastal response to waves is examined under the presence of seven emerged breakwaters of similar characteristics. However, because the Kolymvari sandy coast is a sea turtle nesting beach, an alternative solution is also investigated, i.e. three of the seven breakwaters are considered submerged ones, proved to be more appropriate for the nesting habitat of sea turtles.

METHODOLOGY

The sequences of wave events of different intensities and durations were extracted from wave timeseries that occurred throughout 2021, following the methodology developed by Malliouri et al. (2023). Additionally, coastal processes including wave propagation from deep waters towards inshore, coastal circulation, sediment transport, and sea bottom evolution were simulated using the MIKE 21 Coupled Model FM software package (DHI). Then, 3 sets of simulations were performed that used the same input data, preserving wave chronology and providing results at characteristic time intervals, listed below:

1. Simulation under the presence of three emerged breakwaters (Present situation)
2. Simulation under the presence of seven emerged breakwaters (Alternative case)
3. Simulation under the presence of four emerged and three submerged breakwaters (Environmentally friendly case)

CONCLUSIONS

A cost-effective method is implemented, providing information on sea bottom evolution as a time function. In addition, by considering site specific environmental aspects related to the studied coastal structures' types, a balance is attempted between a resilient coastal environment and a suitable nesting habitat for sea turtles.

ACKNOWLEDGMENTS

We acknowledge support of this work by the project "Ecological Quality Assessment of Kolymvari Coastal Zone", funded by the Harbour Management Organisation of Perfecture of Chania.

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Protection of the Poti Coastal Zone from Erosion using Submerged Breakwaters

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INTRODUCTION

The existing erosion processes of the city Poti and its maritime region are mainly caused by the reduction of the water flow of the the Rioni River "City Canal" and the sedimentation with solid sediment of its stream canal. The volume of beach-forming sediment deposited in the river bed is about 1,000,000 m^3, and the sediment deficit in the coastal zone is about 200,000 m^3.

In order to develop erosion protection measures for the coastline south 6 km section of the "City Canal", is divided into two parts: a) The 1-km long coastal strip adjacent, where the riparian currents arising as a result of the flow of the Rioni River into the sea are strong; b) The rest of the coastline, where the influence of the Rioni River is weak. 100-meter long sand-filled geotubes should be installed at the beginning and end points of the 1-km section of the bank to prevent sediment loss. In order to fill the deficit of sediment, it is necessary to clean the river bed "City Canal" by means of a suction device. The extracted material will be dumped through a pipeline in a 1 km strip adjacent to the channel, which will then be processed and distributed by the waves.

MAIN PART

In order to protect this part of the shore from erosion, we will use the method of placing to multiple submerged breakwaters (SBW) parallel to the shore. Will be used geotextile pipes (geotubes) filled with sand as SBW. The use of submerged geotubes is justified both economically and ecologically (Fig. 1). The main geometric parameters of submerged geotube placement are: length of the geotube -L_b, width - w_b, height – d, its distance from the shore -x_b, distance between geotubes - L_g and depth of geotube crest under water -a. For Poti coastline, it is convenient to place geotubes $x_b = 100;\ 180$m, from the shore, where the water depth is $h_b = 2;\ 3$m.

Below is representeted the calculations for the given parameters: $a = 0.5;\ 0.7$m. $L_b = 120, 180$m. $L_g = 60;\ 120;\ 180;\ 240$m.

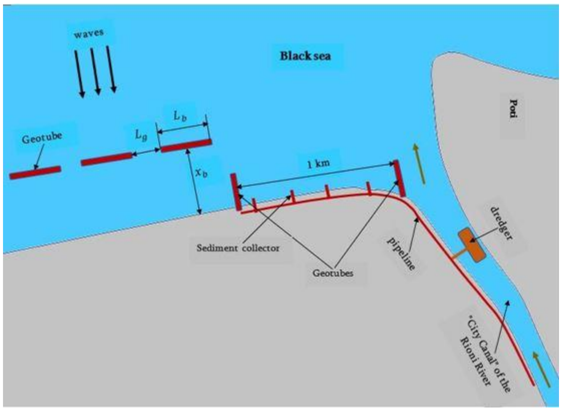

Fig.1 Erosion protection scheme for Shore.

The contribution of the variation of the lateral confinement ratio ($m = \frac{L_g}{L_b}$) can be analyzed using the cumulative sediment displacement values in the lee of the SBW. The different degree in wave sheltering is shown to be dependent on the relative wave height ($\frac{h_b}{H_i}$) with h_b being the depth at the location of the breakwater. Based on these relations the following equation can be derived for the location of a data point on the x - axis :

$$x = \left(\frac{a}{h_b}\right)^{\frac{3}{2}} \left(\frac{L_b}{h_b}\right)^2 \left(\frac{A^3}{h_b}\right)^{\frac{1}{2}} \left[1{,}22\left(\frac{L_g}{L_b}\right)^2 - 3{,}67\left(\frac{L_g}{L_b}\right) + 3{,}22 \cdot i \cdot \left(\frac{h_g}{H_i}\right)^2\right], \quad (1)$$

$y = \frac{h_b}{H_i}$, H_i is the height of the wave at SBW, $\frac{h_b}{H_i} \geq 1{,}25$ and $0{,}25 \leq \frac{L_g}{L_b} \leq 2$. The functional dependence determining the shore reaction between the system parameters is expressed by the formula:$y = 2\log_{10} x + 0{,}65$.

The graph of function y in semi-logarithmic scale is a line. If the points calculated for the values of the system parameters are placed on the graph to the left of the line, then the reaction of the bank is accumulative, and on the right - erosive (Ranasinghe et al.2010).

The character of the morphological change of the shore after the placement of submerged geotubes is determined by the formula: $r = \frac{\eta + \eta_b}{\eta_g}$. In this equation, η is the water elevation rise after the wave passes over the geotube; η_b - the water elevation rises during the breaking of a new wave at the shore; η_g - water elevation rise after the undisturbed passage of the waves between the breakwaters and breaking on the shore (Bellotti, 2007).

It is known that when $r > 1$ - the shore is eroded. When $r < 1$ the shore is accumulative (Villani et al. 2012).

The following equations are used to calculate η:

$$\frac{q_1^2}{g(h_2+\eta)} - \frac{q_1^2}{h_1 \cdot g} + \mu B u_1 h_1 + \eta a + \frac{\eta^2}{2} + C = 0, \quad (2)$$

where $\mu = f_w \frac{\gamma\sqrt{g}}{\pi}$, $\gamma = \frac{H_i}{h_b}$, $B = \int_0^{w_b} \frac{dx}{\sqrt{h(x)}}$, $f_w \approx 0{,}15$, $C = \beta_2 H_t^2 - \beta_1 H_i^2$, $\beta = \frac{1}{8}\left(\frac{1}{2} + \frac{2kh}{\sin 2kh}\right) + \frac{0.9kh}{2\pi}$, k is wave number.

Based on the Poti coast calculations, we choose the geotube placements with following parameters: $x_b = 180$m, $a = 0{,}5$m, $w_b = 5{,}1$m, $L_b = 120$m, $L_g = 180$m.

For such values of the underwater barrier placement parameters, the 5 km long bank located to the south of the "city canal" will be cumulative. Based on the analysis of the obtained results, a scheme for the protection of the coastline has been developed, which is shown on the Fig. 1.

The results obtained by graphical and analytical methods for the similar coastline are in full agreement with the results obtained by numerical model Delft3D.

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Historical Evolution and Impact of Coastal Structures on Shoreline Stability along the South Coast of Cyprus

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INTRODUCTION

Coastal areas are dynamic environments vulnerable to anthropogenic influences and natural changes. Throughout the years, coastal areas have been the center of the communities' cultural, social, and economic development, comprising some of the most productive ecosystems of the world (Costanza et al., 1997). The increase of urbanization in coastal areas along with the combination of natural phenomena, have been the main factors for modifications in coastal dynamics. Sea level rise combined with the increased frequency and intensity of storm surges and strong storms would influence the stability of coastal ecosystems, and further increase their vulnerability.

CASE STUDY AND METHODOLOGY

Due to the dynamic coastal environment, and the erosional problem that most of the coastlines are facing, attempts in battling erosion and stabilizing the shoreline involved, in most cases, the construction of hard coastal structures, without considering their future performance in a changing climate. The coastal area of Limassol, in Southern Cyprus, presents an example of a heavily protected shoreline, having 51 breakwaters and 28 groins in a coastal stretch of 8 km. The present study aims in assessing the effectiveness of hard engineering structures in stabilizing and further protecting shorelines in the vicinity of a changing climate. In cases where traditional coastal construction will be proven ineffective, alternative soft engineering solutions will be proposed. In doing so, the first part of the study focuses on analyzing the shoreline evolution and local morphodynamics as a result of the historical development of coastal defenses in Limassol, Southern Cyprus.

In characterizing accretional and erosional patterns prior and post construction, shoreline positions for the following years; 1970, 1993, 2003, 2008 and 2014 were extracted from satellite data at mean sea level from the Public Works Department of Cyprus. In increasing the accuracy of the observations, satellite derived images indicating the rate of change (m/yr) from 1984 to 2016 were extracted from Luijendijk et al. (2018). Area coverage of Luijendijk et al. (2018) data was overlapping the one from the Public Works Department, allowing comparison between two independent satellite sources.

RESULTS AND CONCLUSIONS

In depth analysis was performed for two selected case studies in Limassol; Vathia (Fig.1) and Germasogia beach areas. In the present study, coastal structures dictate, to some extent, in both cases, the sedimentation process by affecting longshore sediment transport. Overall, significant accretional patterns were not observed when comparing the shoreline of 1970 and 2014 as a result of coastal defense construction in the greater stretch of Limassol. However, accretional and erosional patterns, as expected, were observed in between constructional events on the updrift and downdrift sides of the structures, respectively. Significant accumulation of sediments observed in the downdrift areas, specifically in the shadow of the structures are believed to be mainly due to construction factors and not solely due to natural reasons.

Conclusions on that resulted from the fact that illegal construction was performed by hotel owners, aiming to create a wider beachfront, thus trapped sediments in the area were redistributed once illegal structures were dismantled and a series of breakwaters were constructed. Additionally, alluvial sediment supply from Vathias and Germasogia rivers is very limited post dam construction, thus supporting the original hypothesis that relocation of sediments, giving rise to the observed trends, is mainly due to construction reasons. For the two selected case studies, analysis demonstrated that coastal defense structures were proven effective in attempting to stabilize the shoreline, which was expected when taking into consideration the magnitude of construction settlements found in the area. Observations and conclusions drawn from this study provide an insightful base for the implementation of numerical modeling in understanding and foreseeing future morphodynamic responses of a protected shoreline under different climatic scenarios.

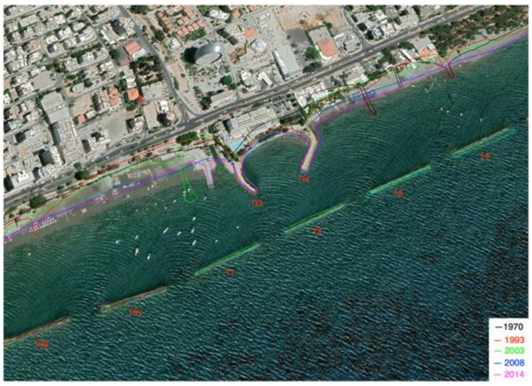

Figure 1. Satellite derived shoreline image for Vathia beach area, with shoreline positions over time indicated with different colors.

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Evolution and Trends of Coastal Erosion along the Nestos River Delta

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INTRODUCTION

The coastal zone is a dynamic geomorphologic system in which multiple changes occur at diverse temporal and spatial scales, mostly affecting the shoreline position response through erosion/deposition actions, resulting from natural and anthropogenic activities (Van Rijn, 1993). Natural effects include shoreline interactions with incident waves, tides, storms, tectonic processes, and sediment loads reaching the coastal zone through the hydrologic network of the adjacent watershed (Louati et al. 2015). Anthropogenic effects are linked to the mismanagement of coastal structures, dredging activities, dam construction upstream a river, intense tourism, overpopulation, etc. (Williams et al., 2018). In parallel, climate change is expected to induce further pressure on coastlines due to Sea Level Rise (SLR) effect and the increase in storminess (Zhang et al., 2004). Coastal authorities are faced with the increasingly complex task of balancing development and managing coastal vulnerabilities and risks. In that sense, the Integrated Coastal Zone Management (ICZM) provides a framework to resolve conflicts, mitigate impacts of short-/long-term uses, and support strategies for sustainable coastal management.

MATERIALS AND METHODS

To assess coastal erosion over time, all historical shorelines at were extracted from Landsat 4-5 TM, Landsat 8 OLI, and Sentinel 2 satellite sensors. In parallel, using a series of algorithms, data from historic meteorological and oceanographic databases, describing winds, coastal currents and waves were retrieved from external platforms and systems (e.g., from CMEMS, NOAA, SeaDataNet). Topographic data adjacent to the examined shoreline catchment were retrieved from the Advanced Land Observation Satellite (ALOS) Global Digital Surface Model. Bathymetric data at the nearshore and offshore study area were retrieved from the European Marine Observation and Data Network (EMODnet). Nestos River hydrologic data were retrieved from the Swedish Hydrometeorological Institute (SMHI).

RESULTS

Along the western part of Nestos Delta, slight accretion (~ 0.4 ± 0.1 m/year) is observed from 1985 to 1995. On the contrary, over the next decade (1995 - 2005), high erosion rates (up to 1.7 ± 0.1 m/year) were reported. This is the period in which the delta is strongly affected by the lack of sediments due to Nestos River damming (1996). The coastline recovers, almost to its initial position, characterized by average accretion rate of 1.1 ± 0.1 m/year, in the 2005-2015 period. However, accretion is mostly limited at the Ammoglossa area (average accretion rate 1.7 m/yr), due to the wave refraction and diffraction around Thassos. Overall, significant spatial variability is observed along the shoreline, throughout the examined years. The western sub-area is characterized as "slightly eroded", since the difference at the average position of the 1985 and the more recent 2015 shoreline is approx. -2.3 m. Keramoti Gulf exhibits the highest, chronic coastal erosion with trend up to -2.2 ± 0.1 m/year.

The eastern part of Nestos delatic zone the shoreline retreats with average rate of -0.8 m/yr. The highest reosion rate is seen in the 1995 – 2000 (-1.1 m/yr) and 2000 – 2005 (-2.6 m//yr) periods. The highest erosion rate is observed at the coastal area to the east of Nestos River mouth (~ -3.4 m/yr). Over this 30-year period, the shoreline retreated by up to -106 m. To the north-eastern coast, the coastline seems balanced characterized by limited accretion and erosion rate (up to ± 1 m/yr). The beaches exhibiting the higher sediment accumulation are located at both sides of the Erasmio lagoon inlet.

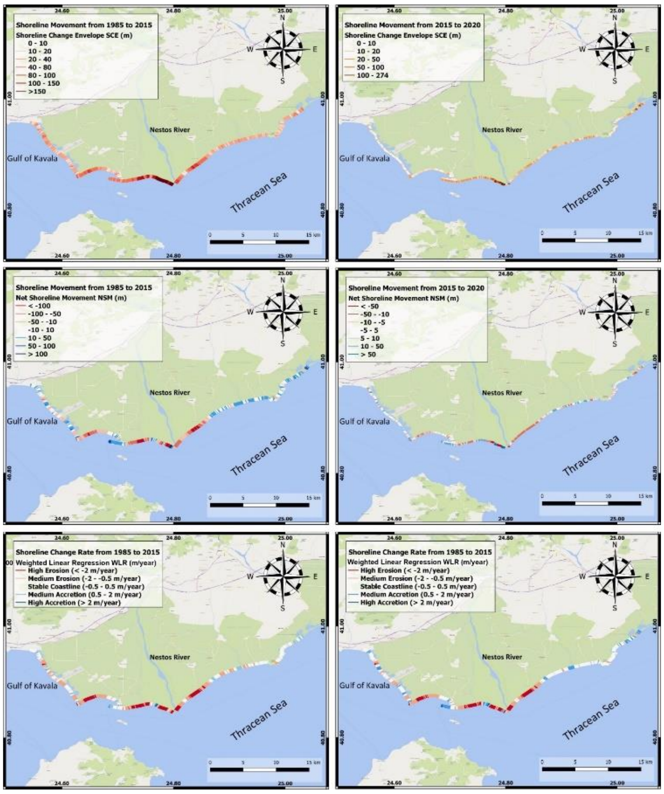

Figure 1. Statistical parameters (SCE, NSM, and WLR) estimated; a) for the period 1985 to 2015 (left column), and b) for the period 2015 to 2020 (right column).

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Climate Change Impacts on the Coastal Zone of Alfios River Estuary

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INTRODUCTION

Coastal erosion can lead to more frequent and intense coastal flooding that threatens human life and causes serious damage to infrastructure in coastal zones. Sea level rise and extreme events, due to climate change, are projected to exacerbate risks for coastal communities, especially in low-lying coastal areas. Therefore, in order to increase coastal preparedness against erosion and flooding events, the physical processes taking place in a coastal zone should be investigated for the coming years. Hence, the present study focuses on investigating, by means of numerical modelling, the nearshore wave and hydrodynamic field along with the corresponding sediment transport field and rates of bed level change, for the next decades, around the Alfios River Estuary in the coastal zone of Municipality of Pyrgos in Greece.

METHODOLOGY AND DATA

The main goal of this study is to determine the evolution of erosion and sedimentation trends along the coast zone of Pyrgos, on either side of the estuary, under different Representative Concentration Pathway scenarios. The methodology followed herein is based on the following steps. First, reliable sea state data are obtained from the Copernicus open database. Particularly, wave climate (significant wave height, peak period and mean wave direction), mean sea level rise and storm surge elevation data were obtained for three periods: 1979 to 2019 accounting for previous decades and 2041-2100 accounting both for RCP4.5 and RCP8.5 scenarios. Having statistically analyzed these data, equivalent waves are determined for each of the directions that the coastal study area is exposed to, representing the mean annual wave climates for the three periods. Indicative wave rose diagrams are shown in Figure 1.

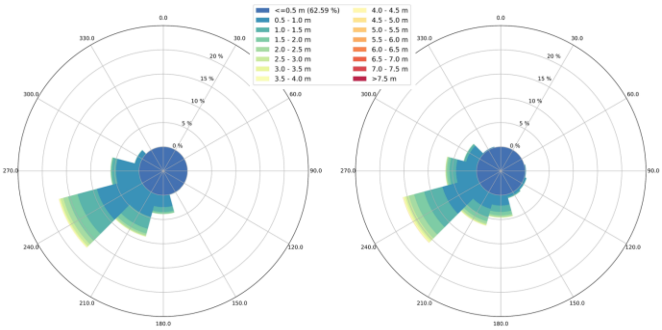

Figure 1. Wave rose diagrams of mean annual wave climates. Left: 1979 to 2019; Right: 2041-2100 for RCP8.5.

As a next step, the bathymetric grid is constructed based on data retrieved by nautical charts and field surveys and accounting for different mean sea water levels. Subsequently, the Initial Sedimentation and Erosion modelling concept (Chondros et al. 2022) is adopted to determine the sedimentation and erosion trends in the coastal study area. In particular, for each considered equivalent wave, the spatial distribution of nearshore wave heights and radiation stresses are first simulated with the Maris PMS (Scientia Maris, 2022), a nonlinear mild-slope wave model of parabolic approximation. The radiation stresses are then fed to the hydrodynamic model, Maris HYD, to simulate the nearshore currents to compute the surface elevation and the current velocity components. Wave and hydrodynamic results serve as input to the last numerical model of the chain, i.e., the Maris SDT, a sediment transport and morphological model, to ultimately determine the rates of bed level changes. In addition to the annually averaged trends, extreme wave conditions (Figure 2) are simulated to investigate further on the acute erosion trends.

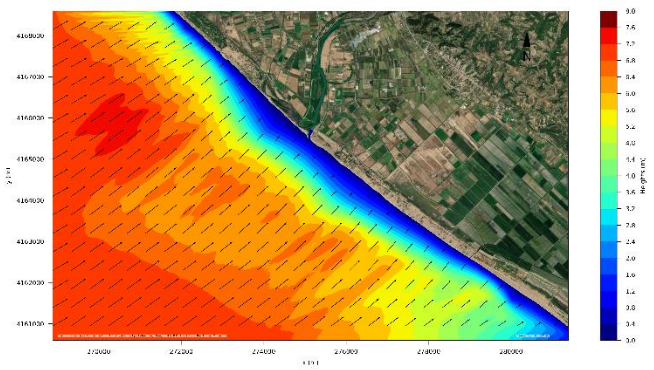

Figure 2. Nearshore wave height field at the coastal zone of Alfios river estuary for an extreme West-NorthWest incident wave (H_{so} = 7m and T_p = 13s,) appeared in the RCP8.5 dataset.

DISCUSSION

Based on the findings of the present study, the coastal zone of Pyrgos will become more vulnerable to erosion and consequently to coastal flooding events. The mean sea level rise in conjunction with the extreme wave conditions will lead to alteration of coastal processes, enhancing erosion trends.

ACKNOWLEDGEMENTS

This research is carried out in the context of the project “Adaptation to Climate Change Through the Development of an Early Warning System for Compound Coastal Flooding: Implementation in the Alfios River Estuary in the Coastal Zone of Municipality of Pyrgos, Greece - EWS_CoCoFlood” under the call for proposals “Physical Environment & Innovative Actions 2022 - Priority Axis 3 "Research and Application"”. The project is financed by the Green Fund (3523 - 699/2022).

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Perched Beach Nourishment against Coastal Erosion and Flooding: Experimental and Numerical Simulation

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INTRODUCTION

Beach nourishment combined with a submerged structure is a very common method against beach erosion and flooding. The response of the cross-shore hydro-morhodynamics depends on the interaction between the waves, the submerged reef, and the characteristics of the artificial beach. The reef dissipates and reflects the wave energy and obstruct the sand from drifting seawards (Gonzalez et al., 1999).

EXPERIMENTAL METHODOLOGY

The experiment has been conducted (in a 1:20 scale) in the Laboratory of the Department of Hydraulics and Environmental Engineering, Aristotle University of Thessaloniki, Greece. A sandy beach was formed in a 14.05 m long wave flume. The flume was 0.40 m. wide. The slope of the surf-zone was set equal to 1:10. The water level was 0.28 m. A submerged structure, made of geotextile material, was placed one meter (towards the shore) from the point where bed slope (1:10) begins. The freeboard was 9 cm. A well sorted fine natural sand of d_{50}=0.2 mm is used in the experiments. Four wave periods were selected, T = 1.00 sec, T = 1.25 sec, T = 1.54 sec, T = 2.00 sec. The wave height was constant and equal to 0.1 m (H = 0.1 m) and 0.04 m (H=0.04 m). The beach fill slope was 1:2 and 1:4 respectively. The berm height of the beach fill was B=0.05m.

NUMERICAL MODEL

Cross-shore morphology evolution of a nourishment project is simulated by an improved version of the Boussinesq nonlinear wave model described in Spyrou and Karambas (2021). The hydrodynamic model (wave and undertow model) provides to the sediment transport model all the required information (wave height, bottom velocity, wave energy dissipation, mean sea level). The bed load transport (including sheet flow sediment transport rate and suspended load over ripples) is estimated with a quasi-steady, semi-empirical formulation, for an oscillatory flow combined with a superimposed current. Phase-lag effects in the sheet flow layer were included through a coefficient. In order to incorporate the suspended sediment transport rate, the depth-integrated transport equation for suspended sediment is solved. More details are found in Spyrou and Karambas, (2021).

EXPERIMENTAL AND NUMERICAL RESULTS - CONCLUSIONS

Figures 1 and 2 show the instantaneous surface elevation, the initial profile, the final profile at the end of the experimental process, and the results from the mathematical model. The presence of the geotextile artificial reef leads to wave reflection and additional dissipation of the wave energy, mitigating the erosive wave conditions.

Together with beach face erosion a bar begins to form near the shore and then it moves seawards as the experiment evolves. It ends up in a position in contact with the submerged breakwater. The submerged structure is an obstacle to further movement of the sand. The sand is not carried seawards but remains trapped between the constructed layout and the shoreline. Also, in comparison with the previous experiments, under the same conditions but without submerged structure (Spyrou and Karambas, 2021), the coastline recession and coastal flooding is decreased. Consequently, the method can be considered as an improvement of the beach nourishment method and can used against beach erosion and flooding. Finally, the cross-shore profile resulting from the numerical application is very well related to the experimental one.

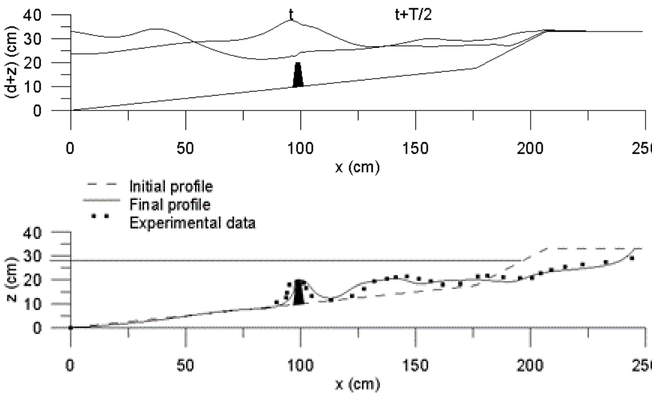

Figure 1. Instantaneous surface elevation, cross-section morphology evolution. H = 0,10 m T=1.54 sec, slope=1/2.

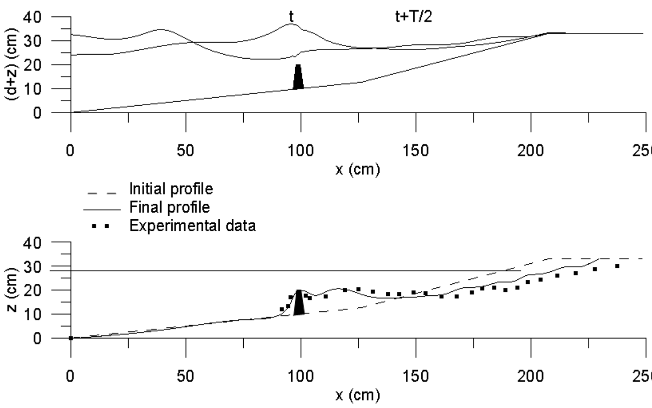

Figure 2. Instantaneous surface elevation, cross-section morphology evolution. H = 0,10 m T=1.54 sec, slope=1/2.

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Wave Regime and Shoreline Evolution of the Coastal Front of Kymi (Euboea)

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INTRODUCTION

The coastal front of Kymi Evia, which is exposed to incoming waves from easterly directions, is partially under erosion. In this paper the wave regime under deep water propagation conditions is investigated utilizing differenert wind data and mathematical approaches (i.e. CEM 1984, 2006),as well as using ERA5- ECMWF wave data. Moreover, the evolution of coastal front over time in the broader area of Kymi is investigated throughthe comparison of a series of aerial photographs and satellite images.

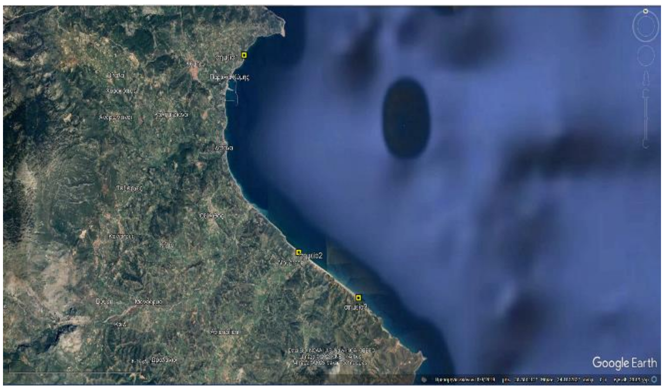

Fig.1 Area under Investigation (From Goggle Earth, 2019)

METHODOLOGICAL APPROACH

The determination of the wave activity was carried out utilizing (i) wind data from the EMY weather station in Skyros and (ii) wind data from thw atlas Athanasoulis and Skarsoulis (1992. For each set of data wave parameters were calculated based on the Sverdrup-Munk and Bretschneider andJoswap equations, whilst the calculations of fetch were performed using different approaches (e.g Smith 1991; CERC, 1984, 2006). In turn, the calculated wave characteristics were compared to wave data provided by the Atlas from Soukisian et al. (2007) and the corresponding statistically processed hourly values of ERA5- ECMWF (height, period and direction).

The study of the evolution of the coastal front was based on the comparison of aerial photographs (1945, 1960, 1978), cadastral orthophoto maps (1998) and recent Google Earth satellite images (2010, 2020). The quantitative comparison of the shoreline evolution was achieved with the use of DSAS tool (Thieler et al., 2009).

Results – Discussion

Fetches estimated with different methods present remarkable differences, whilst wind data is characterised by smaller ones. Signifficatly differences present also the predicted wave characteristics (Hs, Tp) estimated by the prognostic equations compared to those calculated by the wave metatada. In general, the Kymi coastal sector is exposed primarily to NE and SE waves and secondarilti to those approaching from the E and N.

The evolution of the coast is contrlloed by the incoming wave energy, coastal morhology,the presence of river mouths and human interferrience. Waves are responsible for the inshore sediment distribution and/or their removal together with the magnitude of erosion undegone subaerial beach zone and coastal cliffs. Rivers, although small in size and of empemeral flow, seems to provide adquate volume of sediment (even sporadically). Erosion mostly takes place in some northern sectors being associated with the presence of two groins and the piers of the port. It is also investigated if changes of wave regime, in terms of storm intensity and frequence of occurence has been contributed to coastlinew evolution.

ACKNOWLEDGMENTS

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A Sideways Look at 1-Line Beach Modelling

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INTRODUCTION

This paper presents a personal view of the 1-line beach concept, how it has developed from its origins to be an integral part of coastal engineering practice and explores some new potential applications.

HISTORY

The 1-Line beach model was originally proposed by Pelnard-Considère (1956) on the basis of experimental observations. It was subsequently established on a theoretical basis which is based on a combination of the continuity of mass and a longshore sediment transport equation (Larson et al., 1997). The primary assumptions are: (a) the beach profile is in equilibrium and is unchanging in time, (so that one contour is sufficient to predict the entire beach); (b) The longshore sediment transport takes place up to a specific depth known as the depth of closure. As the model can be reduced to an equation of the diffusion type, early results were found from analytical solutions. The advent of computers saw computational methods for solving the 1-line model flourish, so that 1-line modelling is now an indispensable tool for coastal management.

ANALYTICAL DEVELOPMENTS

Analytical solutions had been restricted to constant and uniform wave conditions, and relatively simple beach geometry. More recently, new solutions which incorporate arbitrary initial conditions, time-varying wave climate and more complicated configurations have been derived (e.g., Reeve, 2006; Valsamidis & Reeve, 2017, 2020). Such analytical solutions provide a wider set of benchmark cases against which to test computational models, particularly with regard to time-varying wave conditions.

COMPUTATIONAL DEVELOPMENTS

Computational solutions are usually based on solving three equations, rather than the one used for analytical solutions. This permits the removal of the small angle restriction and allows additions such as wave transformations, alongshore and time variation of wave conditions, which are incorporated into commercial versions of the model such as GENESIS, UNIBEST and LITPACK. Shoreline evolution can be computed for a sequence of wave heights and directions, and these can also vary along the length of the beach.

Computational models offer greater flexibility but are constrained by the choices of computational scheme, boundary conditions and resolution. Extensions to the 1-line model such as simulating multiple lines or multiple sediment sizes have been investigated but have failed to gain traction with practitioners in the same way that the 1-line model has.

Cellular methods have been used for wide angle wave attack which can simulate the formation of spits (Ashton & Murray, 2006). This approach has proved popular as it can deal with highly deformed shoreline shapes, but it relies on the user providing probability distributions of wave heights and directions rather than a sequence of wave characteristics.

APPLICATIONS

The 1-line concept is widely applicable, with caveats, and has recently been used to understand the development of the Dutch 'Sand Motor' mega-nourishment scheme. The comparison study of Whitely et al. (2021) demonstrated the strengths and weaknesses of analytical and computational models.

The speed and ease of use of the 1-line model means it is ideal for Monte-Carlo simulation to estimate typical behaviour and variance about this. This technique was pioneered by Vrijling & Meijer (1992) who investigated beaches near port breakwaters. This approach has since been used in many applications but specifically in understanding the importance of storm sequencing in the evolution of beaches near groynes (Reeve et al. 2014).

CONCLUDING REMARKS

The final paper will include a brief summary of the historical development but will focus on the applications mentioned above, specifically how the 1-line concept could be useful in ensemble modelling and reliability calculations. With the introduction of probabilistic design such applications are becoming more significant. If proven to provide a useful degree of dependability, the 1-line approach may offer an efficient and economic alternative to running more complicated physics-based models for probabilistic design applications.

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Effects of Flow and Sediment Parameters on Vortex Ripple Morphodynamics

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INTRODUCTION

The complex interactions between sand and wave-generated flows lead to the generation of sand ripples. These structures are created due to the flow vortices developed on the leeside of their crests during each half cycle of the oscillatory flow, and they are described in the literature as vortex ripples. The size of ripples is crucial for the sediment transport processes in coastal environments, since it affects the bottom friction and the wave boundary layer. The objective of the present study is to investigate numerically the effect of different values of the mobility parameter, ψ, and the normalized sediment size parameter, a_o/D_g, on the morphodynamical development of vortex ripples. An LES model is utilized for the numerical simulation of the 3D turbulent oscillatory flow, coupled with the corresponding sediment transport and bed morphodynamics. Several cases were simulated regarding ripple creation and growth.

METHODOLOGY

The governing 3D fluid motion equations are the continuity equation and the Navier-Stokes (NS) equations. The 3D Immersed Boundary method (Dimas and Chalmoukis, 2020) is implemented for the imposition of the non-slip velocity boundary condition on surface of the mobile bed.The semi-empirical formula in Engelund and Fredsøe (1976) is used for the computation of the bed load transport rate, while an advection-diffusion equation is used for the computation of the concentration of the suspended sediment. A two-stage time scheme is utilized for the temporal discretization of the NS equations. In the first stage an intermediate velocity field is computed using a 2nd order Adams-Bashforth scheme. The final velocity field is computed in the second stage of the time-step. The solution is based on the dynamic pressure, which is obtained by the solution of a Poisson equation. 2nd order central finite differences are used on a staggered Cartesian grid for the spatial discretization of the NS equations. The coupling between the evolution of bed morphology and the sediment transport fluxes is obtained by the numerical solution of the conservation of sediment mass (Exner) equation. The sediment transport mechanisms comprises both bed and suspended load transport rates. In order to mimic as possibly the natural morphodynamical process in the vicinity of ripple crests, an avalanche function is included in the morphodynamical model, when the bed slope exceeds a specific limit. For the temporal discretization of the Exner equation a 3rd order Adams-Bashforth scheme is applied in both horizontal directions, while 2nd order central differences were used for the spatial gradients.

RESULTS AND DISCUSSIONS

Ripple formation and development was examined initiating from an almost flat bed with a small perturbation in the middle of the computational domain. Periodic boundary conditions were applied in the horizontal directions for all variables (velocity, pressure, sediment concentration and bed level), so that ripple development is not spatially limited by the boundaries. A zero Dirichlet boundary condition is applied at the bottom boundary, while appropriate rigid-lid boundary conditions are applied at the upper boundary. In Figure 1, typical snapshots are presented during ripple development for ψ = 50 and a_o/D_g = 500. The initial hump grows rapidly in height and it expands in the spanwise direction during the first periods. At the same time, small perturbations are emerging on each side of the initial hump. After 20 wave periods, the bed is almost fully covered in small ripples. During the next periods, merging phenomena take place, with the bed geometry being fully covered with ripples that present spanwise three-dimensionality and close to the predicted final form after about 100 waves. During the next periods, phenomena of ripple merging and annihilation occur, the spanwise three-dimensionality vanishes, which eventually leads to ripples that present spanwise two-dimensionality. The equilibrium geometry of the bed is reached after about 150 wave periods, and comprises three consequent ripples with dimensions of ripple length, L_r = 0.9a_o and ripple height h_r = 0.139a_o. The calculated ripple dimensions are well within the range of the experimental data used to fit the empirical formulas in Nielsen (1981).

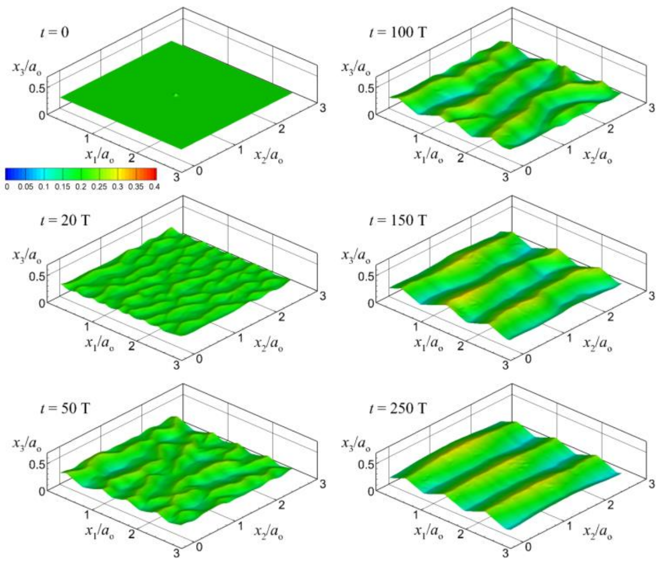

Figure 1. Numerical result of ripple creation from a flat bed for ψ = 50 and a_o/D_g = 500. The equilibrium state is reached after 150 wave cycles.

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Representative Waves for Estimating Annually Averaged Sedimentation and Erosion Trends in Sandy Coastal Areas using Numerical Models and Artificial Neural Networks

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INTRODUCTION

Process based numerical models are widely recognized as a valuable tool for simulating and predicting changes in coastal bed morphology. However, despite their prevalent use in coastal research studies, they are highly intensive in computational resources and processing capacity, therefore requiring the employment of wave schematization methods in order to reduce the required wave input data and accelerate the simulation processes. This paper introduces a new methodology of wave input reduction, combining the use of numerical modelling and Artificial Neural Networks (ANN), in order to derive a set of representative wave conditions that is morphologically equivalent to the full wave climate. The proposed approach utilizes time series of offshore wave characteristics (height, period and direction) that can be obtained from open databases and bathymetric data for the coastal area. The representative sea states are calculated by a trained ANN and are then used as inputs in the simulations carried out by the numerical models in order to obtain predictions on the evolution of coastal bed morphology.

NOVEL METHODOLOGY

The proposed herein methodology, building upon the concept of Initial Sedimentation and Erosion (ISE) modelling and existing methods of wave schematization, comprises of two main parts. In the first part, a set of different scenarios with distinct incident waves is selected in order to set up and train the ANN. These different sea-state scenarios are subsequently simulated in order to produce the rates of bed level changes, that will be used as target outputs for the ANN. The numerical models (developed by Scientia Maris) utilized, include a parabolic mild slope wave model (Maris PMS) a hydrodynamic model (Maris HYD), and an initial sedimentation/erosion and morphological model (Maris SDT). Several architectures were examined in order to optimize the performance of the network before selecting a Multilayer feed-forward ANN with two hidden layers, each containing 8 hidden neurons.

In the second part, the multivariate wave climate is divided into equally spaced directional bins of 22.5° which are then further grouped by significant wave height with an interval of 0.5 m. For each of the abovementioned wave classes, the mean values of the characteristic parameters found in the wave class (i.e. the significant wave height (H_s), peak period (T_p) and mean wave direction (MWD)) are then calculated and fed as input to the trained ANN.

The output of the ANN's processing will be the characteristics of the representative wave of each directional bin, which consist of the equivalent wave height H_e, the equivalent period T_e (s), and the equivalent mean wave direction MWD_e (°), per each sector. In the final step, the simulations are performed for each of the equivalent sea-states calculated. The results produced (i.e., the rates of bed level changes calculated by the SDT) are then integrated by assigning the frequency of occurrence as weights to the different incident wave scenarios in order to obtain the full sedimentation/erosion profile of the coastal area.

APPLICATION AND RESULTS

The proposed methodology is applied and evaluated against two other methods of wave schematization in the coastal zone of the archaeological site of Archontiki in Psara Island, in Greece, as a case study. The methods used in the assessment of the proposed method's performance are described as 'Classical Approach' and the methodology proposed by Chondros et al. (2022) which also rely on ISE modelling.

The three methodologies are applied in order to compute rates of bed level changes and estimate sedimentation and erosion trends in the area. The results of the CA are then used as a benchmark in the evaluation of the accuracy of the proposed method compared to the Chondros et al. method. The main performance metric considered is the Brier Skill Score, an index widely used in evaluating the performance of morphological evolution models.

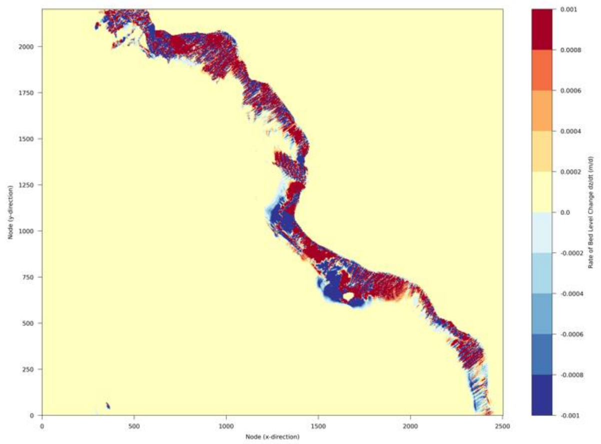

Figure 1. Annually Averaged Rates of Bed Level Change adopting the proposed approach

CONCLUSIONS

In the light of the findings, it can be deduced that the innovative methodology proposed by this research can determine representative waves that can drastically reduce the required simulation effort while simultaneously preserving the accuracy and reliability of the results. Future research could concentrate on enhancing the training of the developed ANN by incorporating more parameters like sea bottom slope, sediment grain sizes and wave characteristics.

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Revisiting and Enhancing the Concept of Equivalent Wave Heights

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INTRODUCTION

The method of calculating of equivalent wave heights (EWH), capable of replicating the morphological bed level evolution induced by the full timeseries of offshore wave characteristics, has been utilized in coastal engineering practice for several decades (Chonwattana et al., 2005). This method, based on separating the tri-variate wave climate in bins and calculating equivalent waves based on the energy flux potential of each bin aims to reduce the model run-time required for the demanding morphological simulations. Despite the widespread usage of this method, a research effort concentrating on examining enhancements of this method and systematically evaluating model results has not been undertaken yet.

The objective of this research is to further expand on the concept of EHW, provide and evaluate possible enhancements to increase the reliability of model results while keeping computational effort at a minimum.

METHODOLOGY

A detailed evaluation of the alternative configurations of the EWH method was performed in the coastal area of the Port of Rethymno, Crete, Greece implementing the coastal area model MIKE21 CM FM. Hourly changing offshore sea-state characteristics were extracted from the Copernicus database for the year 2012. A "brute force" simulation containing a detailed wave climate of 68 sea-states, was used as a benchmark to evaluate the performance of each configuration.

Apart from the classical method of Chonwattana et al., 2005 (test EWH-01), three additional tests were realized based on the following:

- Test EHW-02: Subdivision of each directional bin based on the average energy flux capacity of said bin.
- Test EHW-03: Definition of "transition" bins where longshore or cross-shore transport is responsible for the calculation of equivalent waves.
- Test EHW-04: Training and implementation of an Artificial Neural Network, to eliminate sea-states unable to initiate sediment motion and calculation of the equivalent waves based on the principles of EWH-02.

For a fair comparison, 12 equivalent wave characteristics were calculated and set constant for each test. To evaluate model performance, the Brier Skill Score (BSS) metric (Sutherland et al., 2004), widely used in morphological applications, was calculated for the sandy coastline adjacent to the port. Values greater than 0.5 indicate an "Excellent" model performance.

RESULTS & CONCLUSIONS

A significant model run time reduction (about 450%) was observed when reducing the forcing input from 68 to 12 sea-states.

In Figure 1, the bed level change results calculated by implementing the MIKE21 CM FM model forced with the wave characteristics of the brute force simulation (top) and EWH-04 (bottom) are shown.

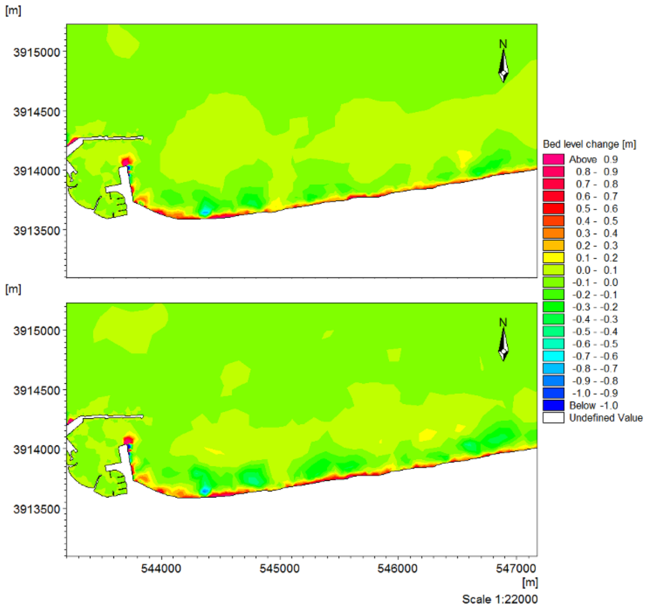

Figure 1. Computed bed level change by implementing the "brute force" simulation (top) and EWH-04 method (bottom).

The calculated BSS values of each test are shown in Table 1. It is observed that a signficant model performance increase is achieved in all tests (EHW-02, EWH-03 and EWH-04) compared to the default test (EWH-01). In particular, the default test gave a "Good" model performance, while all the newly conceptualized tests are clasified as "Excellent" with respect to the BSS classification. Ultmately, the best performing test was EWH-04, which incorporates an ANN to eliminate sea-states that are considered insignificant in shaping the morphological bed evolution.

Table 1. Calculated BSS of each EWH test

	EWH-01	EWH-02	EWH-03	EWH-04
BSS	0.24	0.56	0.58	0.65

The methodologies presented in this research are considered a valuable tool for engineers and scientists, desiring to obtain more accurate model results and reduce the computational burden, based on the principles of a method implemented widely in coastal engineering practical applications.

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Wave Input Reduction Methods for Annual Bed Evolution Applications

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INTRODUCTION

The prediction of the bed level change at an annual scale is of particular interest to engineers, scientists and the public due to the strong implications to the environment, economy and community safety. Traditionally, coastal area models are applied to predict the coastal bed evolution, however they are associated with staggering computational burden. Hence, various wave input reduction (IR) methods have been developed all aiming to reduce the forcing input of the numerical models. The input reduction methods can be divided in three branches:

- "Representative morphological" or "equivalent" wave height selection methos
- Binning input reduction methods
- Clustering algorithms

The objective of this research is to further expand on the concept of Input Reduction, provide enhancements in all three branches and thoroughly evaluate results and incorporate machine learning to both improve model results and further reduce the computational effort.

MATERIALS AND METHODS

A detailed evaluation and intercomparison of the wave input reduction methods was performed in the coastal area of the Port of Rethymno, Crete, Greece utilizing the coastal area model MIKE21 CM FM. Hourly changing offshore sea-state characteristics were extracted from the Copernicus database for the year 2012. A time-consuming "brute force" simulation containing the full timeseries was used as a benchmark to evaluate the performance of each IR method.

Several configurations and enhancements, leading to over 12 tested IR methods, were conceptualized and implemented focusing mostly on the following aspects:

- elimination of sea-states considered unable to initiate sediment motion using a complementary numerical model to estimate bed shear-stress due to waves,
- improve the reliability of clustering algorithms by introducing quantities responsible for the longshore sediment transport,
- revisiting and enhancing the concept of equivalent wave heights by introducing an Artificial Neural Network (ANN) tasked with the elimination of lowly energetic sea-states.

The training and implementation of the ANN is of particular interest, since it can both consider the complex interaction of waves, hydrodynamics and morphodynamics, without increasing the required computational effort (Papadimitriou et al., 2022). For a fair intercomparison, 12 representative wave conditions were set for each examined IR method. In Figure 1, the obtained representatives by implementing the equivalent waves method including the ANN are showcased.

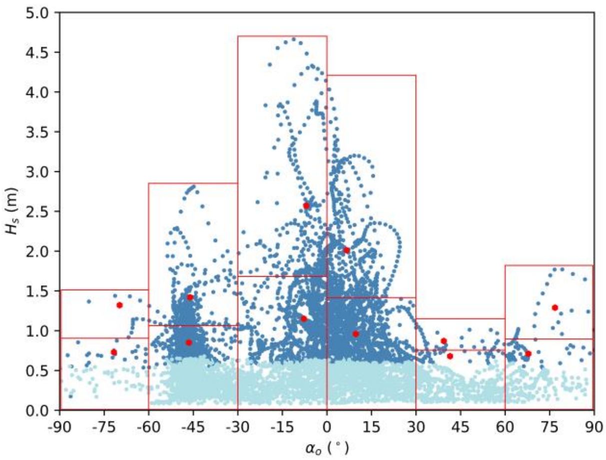

Figure 1. Obtained 12 representative wave conditions (red markers) by implementing the method incorporating the ANN.

To evaluate the performance of each IR method, the commonly used Brier Skill Score (BSS) metric (Sutherland et al., 2004) was calculated for the sandy coastline adjacent to the port.

RESULTS & CONCULSIONS

The evaluation of the IR methods focused on not only the obtained BSS (the higher the BSS the better the performance) but also the computational efficiency. After the comparative analysis, it was determined that elimination of lowly energetic sea-states either outright leads to higher BSS values or greatly reduces the computational burden (with a small penalty in performance). The method EW w/ANN was found to be the best one based on these two criteria, achieving reliable results and significant model run-time reduction.

The results of this research have strong implications and provide the engineering community with guidelines and recommendations on which IR method is optimal based on the model configuration as well as the adequate number of wave representative conditions.

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Decision-Making Tool for Mitigation of the Coastal Erosion and Extreme Wave Impacts in the Coastal Zone, in the Context of Climate Change

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SCOPE

The scope of the ILIDA-KIT project is the development of an innovative decision-making tool for the successful management of coastal erosion along with the impacts of extreme wave events; the emphasis is given on coastal zones of touristic interest in the context of adaptation to the ongoing climate change and/or variability.

METHODOLOGICAL APPROACH

The methodological basis of the project implementation is summarized in the following actions:
1.Assessment of natural processes related to coastal zone formation/evolution and to disasters due to climate change and extreme wave events.
The scope is to identify the factors that control the morphological evolution and erosion of beaches, with special attention to climate change-related coastal erosion (CE) and extreme wave events (EWE).
2. Construction of a database that will contain data and information on the current state of the coastal zone.
These will be used to develop the proper assessment indicators for the evaluation of the impact of coastal erosion and extreme wave events, which will be integrated into the ILDA-KIT tool.
3. Development of an Indicator System.
This comprises the development of the scientific methodology for the exploitation of the database records and the development of a system of indicators that will provide the basis for the assessment of the vulnerability of the coastal zone to erosion (present and future) and the spatiotemporal occurrence of extreme wave events, as well as the socio-economic evaluation of their impacts.
4. Design, development and testing of the ILIDA-KIT Decision-Making System Tool. The tool will be tested and validated for operational use and a user-friendly interface will be developed. The final output will be a marketable decision-making tool.

OUTPUTS

ILIDA-KIT will assess the impact of natural factors and human activities on the coastal zone, as well as the potential adaptation measures, in a cost-benefit perspective and with a view to mitigating the impacts of climate change. Therefore, the tool is designed to respond to erosion, due to either natural causes or human intervention, as well as to Climate Variability and Change (e.g., sea level rise, extreme wave events). The innovation of the project lies in the development of a multi-parameter decision making tool (ILIDA-KIT) related to climate change mitigation and resilience to coastal erosion and extreme wave impacts in the context of integrated coastal zone management.
The ILIDA-KIT tool constitutes a multi-disciplinary interactive platform in a GIS environment, functioning through the incorporation of a set of indicators for the various environmental, anthropogeographic and economic factors that affect the coastal zone. The overall purpose of the tool is to be able to indicate the most appropriate intervention measures in the coastal zone in terms of type, size and time, after a cost-benefit analysis, considering the cost of potential losses, the cost of possible interventions, and the potential of future developments in the coastal zone.

ORGANISATIONS INVOLVED

- Ilida Consulting Engineers S.A.
- Institute of Computational Mathematics, Foundation for Research and Technology
- Faculty of Geology & GeoEnvironment, National and Kapodistrian University of Athens

AKNOWLEDGMENTS

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Digitisation and Proactive Management of Coastal and Offshore Infrastructure and Environment

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ABSTRACT

Recent findings of natural gas discoveries in the offshore Eastern Mediterranean Region, i.e., Leviathan in Israel, Aphrodite and Calypso in Cyprus and Zohr in Egypt, as well as future planned exploration by major international offshore operators could contribute significantly to energy security and economic prosperity for the countries in the region. At the same time, renewables are the largest source of energy growth and are set to penetrate the global energy system more quickly than any fuel in human history. In addition to the offshore oil and gas structures and systems that already have been developed and installed, but are still being developed with a growing rate, ocean renewable energy systems (e.g. offshore wind turbines, wave energy converters, combined/hybrid concepts) are currently in the consideration, assessment and design phase. A huge development of coastal and offshore structures is anticipated in near furure; in order to meet efficiently this development safety and environmental protection should be assured.

While the potential benefits of offshore oil and gas as well as the rest of renewable energy technologies exploration are substantial, there are also significant possible negative impacts on the Mediterranean ecosystem which may affect all Blue Growth sectors since infrastructure assets development in coastal and offshore areas are required. Negative impacts may result from accidental or operational hazards, extreme environmental events or other security related risks resulting in loss of life, waste discharge and significant oil spills into the Mediterranean Sea. Such events would have dramatic consequences with main impacts on coastal tourism and fisheries and huge associated financial losses and other catastrophic effects. Effective management schemes for those assets during conception, installation, operation, maintenance and dismantling should be used.

The safe and efficient development of offshore and coastal infrastructures and operational processes as well as the development of the relevant skills to support these industries is of paramount importance. Challenges in connection with condition monitoring, systems integration, materials performance, data, and development of safety codes and standards will be addressed. Those challenges are related with the use of smart technologies for improving the understanding of the physical behavior, ageing and degradation of marine engineered assets and smart proactive management of the whole life cycle from design through to operation, maintenance, life extension and decommissioning.

Towards those needs a National Centre of Excellence has been established for promoting Cyprus as a regional hub for energy, research, innovation, education, and training. East Med Energy Research for Growth and Education Centre of Excellence (EMERGE CoE) has been established within Cyprus University of Technology by faculty members of the Civil Engineering and Geomatics Department.

The creation and installation of in-field monitoring laboratories in cooperation with industry stakeholders has been a key strategic element of the EMERGE CoE's actions, which in turn provides a strong foundation which facilitates many of the above activities. All the aforementioned activities are interconnected and are essential pieces of the puzzle for a successful center. The two initial operational monitoring systems (Figure 1) for measuring the response of marine infrastructures (e.g. accelerations at various coastal jetty and fixed bottom breakwater positions) and environmental factors (wind direction, wind velocity, wave height, temperature, humidity, atmospheric pressure) at two distinct marine locations in Cyprus (the Vasiliko Energy Centre and Ayia Napa Marina) have been augmented by a new monitoring system for water quality parameters installed at the Ayia Napa Marina.

The EMERGE research group is using those significant in-field laboratories as real-time test beds, which will enable many other crucial related activities in line with the center's goals. Over the past few years, the EMERGE research team has worked with two key industry stakeholders, VTTV Vasiliko and Ayia Napa Marina, who provided access to their infrastructure and valuable in-kind support to build up, validate, and operate these systems. In order to facilitate the scopes of the EMERGE CoE's planned study topics, real-time monitored data from the two systems already have been used. It is worth mentioning that three years' worth of data from one of the two systems is currently saved in EMERGE database and is steadily growing. Data analysis already resulted in research publications (Demetriou et al., 2021, 2022) and daily forecasting reports.

Figure 1. Monitoring system in Vasiliko VTTV (left) and Ayia Napa Marina (right), Cyprus.

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A Case-Study for the Water Renewal in the Rio Castle Moat in Greece

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INTRODUCTION

The Rio Castle in Greece was built in 1499, is located at the coast, and originally its moat was connected to the sea both eastwards and westwards. Over the years, the western inlet was blocked due to coastal sediment accretion, and nowadays the moat functions as a semi-enclosed hydrodynamic system with weak seawater circulation and renewal. The objective of this work is to assess the present situation and demonstrate that the placement of a culvert to connect the western part of the moat with the sea will greatly improve hydrodynamic circulation and water renewal.

METHODOLOGY

The effect of waves and the wind-generated currents on the hydrodynamics and the water renewal inside the moat was investigated by coupled numerical simulations of wave propagation and wave- and wind-generated current flow using the MIKE 21/3 (DHI, 2022) software. In particular, the following specific modules of the software were used: MIKE 21 Spectral Waves (SW) for wave propagation, MIKE 3 Flow Model (FM) for wave- and wind-generated currents, and MIKE 3 Transport (TR) for water renewal. The SW module simulates wind-induced wave growth, decay and propagation by solving numerically the wave action conservation equation in an unstructured computational mesh of the bathymetry of a specific area. The spatial discretization is performed using a cell centered finite volume method, and the temporal discretization is based on a fractional time step approach. In the present study, the transport and spreading of a conservative tracer is simulated for the evaluation of the water renewal within the moat of the Rio Castle. A dimensionless concentration of a conservative numerical tracer equal to 1 within the whole moat and 0 outside is defined as the initial condition. Hence, the water renewal can be calculated in terms of the residence time following the evolution of the tracer concentration as determined by the conservation equation. In this study, residence time is defined as the time needed for the concentration of a conservative and passive tracer to reach 1/e (~37%) of its initial value (Thomann and Mueller, 1987). The main wind directions that affect the study area are eastern (E), northeastern (NE), northwestern (NW) and western (W).

The main steps used in the present study are:

- Estimation of the wind speed at 10 meters height, U_{10}, with a one-year return period.
- Estimation of the wave characteristics in deep waters, using a hindcast method based on existing wind data.
- Calculation of the wave radiation stresses with the SW module using the wave characteristics in deep waters for each wind direction as input data.
- Hydrodynamic simulation and evolution of the tracer concentration using U_{10} and/or the radiation stresses as input data.

RESULTS AND DISCUSSIONS

The Rio Castle moat in its present situation acts like a closed hydrodynamic system, due to the presence of a single inlet to the sea in the east side of it. The water renewal is minor, as well as the wind- and wave-generated flow recirculation developed inside the moat. This is in accordance with the stagnant waters and eutrophication problems observed within the moat. On the contrary, with the addition of the western culvert, a significant improvement is observed in terms of water renewal and the moat behaves like a flow-through hydrodynamic system, which is characterized by a dominant flow path with strong currents, enhanced water renewal rates and small residence times. More specifically, with the addition of the western opening, residence times of 18-20 hours are observed within the moat, and the entire water volume is fully replenished after 18-32 hours, depending on the wind case (e.g., NE winds, Figure 1). Due to the particular geometrical characteristics of the moat and the presence of the two bridges around the eastern triangular bastion, a dominant flow path is observed in all cases, which contains the primary west-side channel, and the surrounding south-side channel of the eastern bastion. A secondary and less significant flow field characterizes the remaining areas of the moat, with smaller water renewal rates and larger residence times observed locally. Finally, a significant inflow/outflow is noticed through the moat inlets, in contrast with negligible to zero discharge values through the eastern opening in the present situation.

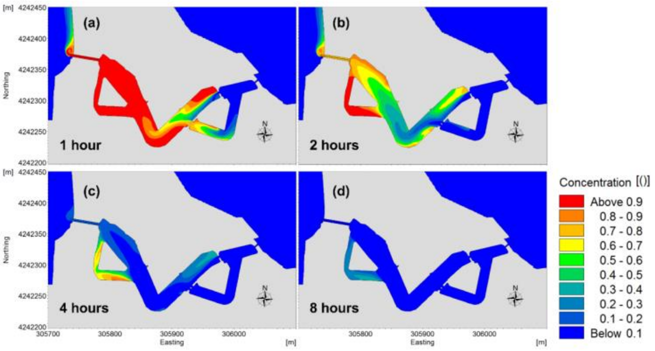

Figure 1. Distribution of the tracer concentration inside the moat (proposed solution) due to NE winds (3 Bf), after 1, 2, 4 and 8 hours.

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A Preliminary Study of Water Renewal in a Flow-Through Lake in Western Greece

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INTRODUCTION

A three dimensional (3D) hydrodynamic and transport model has been applied for the calculation of the flow field and the renewal time in the flow-through monomictic lake Lysimachia, located in the region of Aitoloakarnania in western Greece. The lake has a surface area of 11-13 km^2, which corresponds to +12.5 ~ +14.5 m surface elevation and a water volume 52-57x10^6 m^3, with a coastline length of ~ 22 km, a maximum length of 6.5 km, a maximum width of 3 km, a maximum depth of 7.5 m and a mean depth of 3.7-4.5 m, all during higher free surface level (Kousouris, 2013). The lake has a nearly elongated shape, a relatively large catchment area (314 km^2), and communicates with other larger and much deeper water bodies that seem to determine its flow field and the water renewal. It is affected mainly by the waters from the deepest and largest Lake Trichonida (via a constructed connecting channel), as well as by the inflow waters from the Ermitsa stream, at the northeasterly part of the lake, while it drains its flood waters to Acheloos River. It shows large seasonal fluctuations in water level, while during the winter, it often overflows. The lake is of particular environmental and hydraulic - hydrologic significance, since, after a series of technical hydraulic works, it has been turned into a regulating water reservoir. Regarding the water renewal, the worst case scenario for the Lysimachia Lake includes minimal inflow from the Lake Trichonida and zero inflow from Ermitsa stream.

SIMULATION SET-UP

The numerical simulations have been performed using the commercially available Computational Fluid Dynamics (CFD) code MIKE 3 Flow Model FM Hydrodynamic Module (HD), which is used for the simulation of unsteady 3D flows taking into account density variations, bathymetric data and external forcing. The simulations were based on the numerical solution of the 3D Reynolds averaged Navier–Stokes (RANS) equations with the assumption of hydrostatic pressure. The free-surface is taken into account using a sigma-coordinate transformation approach. For the spatial discretization, a cell-centered finite volume method is followed, using an unstructured mesh approach in the horizontal direction, while a structured mesh is used in the vertical direction. MIKE 3 Flow Model FM Transport Module (TR), also used in the specific work, simulates numerically the spreading and fate of dissolved or suspended substances in aquatic environments under the influence of the fluid movement and the associated diffusion processes. Specifically, the advection and diffusion of a numerical conservative tracer initially applied in the Lysimachia Lake, is simulated numerically under the action of incoming inflows from Lake Trichonida and the Ermitsa stream. The details of the codes can be found in DHI (2018 a, b) and the specific options selected in the runs can be found in Fourniotis et al. (2018, 2021).

RESULTS AND DISCUSSIONS

The hydrodynamic circulation of the lake seems to be affected by the presence of a sand tongue, formed at the northeastern part due to Ermitsa stream outflows, which works as a sandbar leaving waters nearly isolated at the deepest eastern part of the lake. As a result, a central gyre is formed at this area, leading to water entrapment and recirculation and eventually increased residence times. The incoming flood waters from the Trichonida Lake significantly improve the renewal of the Lysimachia waters, regardless the effect of the Ermitsa stream inflow, which is negligible. More specifically, a considerable inflow (~ 22 m^3/s) from the Trichonida Lake generates a flow-through regime from east to west, which is the main reason for the lake´s replenishment. In this case the residence (*e*-folding) time varies from 20 days to 30 days, based on the inflow discharge (Figure 1).

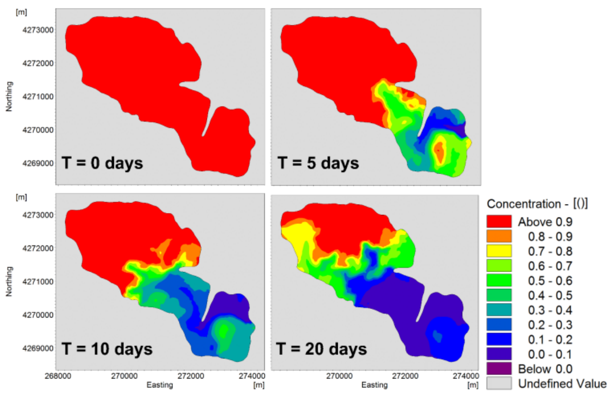

Figure 1.Distribution of the numerical tracer concentration inside Lysimachia Lake, after 5, 10 and 20 days.

ACKNOWLEDGMENTS

Part of this work has been supported by the Region of Western Greece under the research project “Investigation of the hydraulic behavior and suggestions for the regulation of the hydrodynamic system of Trichonida - Lysimachia lakes, in Western Greece”.

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Ground Penetrating Radar for Inspecting the Core and Base of Coastal Sand Dunes

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INTRODUCTION

Coastal erosion induced either by a natural process and/or human intervention has been the subject of extensive investigations due to their negative socio-economic impact.
ILIDA-KIT is an innovative and multi-parametric decision-making tool for successful management of coastal erosion and the impacts of storms. Thus, within the framework of the ILIDA-KIT tool, beach zone sectors of the west and south coast of Peloponnesus (Greece) (i.e. Helonitis Gulf, Kyparissiakos Gulf and Messiniakos Gulf) have been investigated with geophysical means, aiming to the quantification of the sediment budget that is essential for the confrontation of the phenomenon.

The geophysical research aims to identify the thickness and the characteristics of the uppermost lithostarigraphic substratum of the selected beach zone sectors, whose common characteristic is the presence of dunes at the backshore zone. Apart of the other geophysical techniques (e.g. electrical resistivity tomography (ERT), transient electromagnetic soundings (TEM), vertical electrical soundings (VES)) that have been applied, the present contribution provides the preliminary results concerning the application of the ground penetrating radar (GPR) technique.
The GPR electromagnetic method was implemented to profiles normal to the shoreline contributing to (a) the quantification of the erodible part of the beach zone and (b) the determination of the base of the sand dunes.

METHODOLOGY

In total, **22 GPR lines** of GPR were carried out, with a total length of **3391 m** (table 1).

Table 1. GPR lines

Sites	Total Distance (m)
Katakolo (4 lines)	376
Kaiafas (5 lines)	505
Kakovatos (3 lines)	1120
Zacharo (4 lines)	994
Petalidi (2 lines)	115
West Kalamata (2 lines)	118
East Kalamata (2 lines)	163

For this survey a bistatic 100 MHz shielded antenna was used, with the Sensors & Software GPR Noggin 100 system. The data were acquired with a 10 cm trace interval. The electromagnetic pulse transmission and the distance calculation was controlled by an odometer wheel. The traces were averaged, using a unique feature of the system, which controls the number of stacks, depending on the environment and collection speed.

The aquired data were processed in EKKO_Project software, with the application of a standard filtering procedure. Finally, all the geophysical data were topographically corrected through GNSS measurements, acquired with RTK-NTRIP method.

RESULTS - DISCUSSION

The processing results revealed the characteristics (i.e. internal structure) of the uppermost layer of the coastal sites under investigation. This gives the opportunity for the quantification of the possible erodible layer. Moreover, the GPR results highlighted the structure and thickness of the coastal sand dune fields. (Fig. 1).

These findings will guide the future multidisciplinary geophysical survey, whose combined results will define in a much greater detail the attributes of these coastal environments, whose better understanding is pre-requisitive for the development of ILIDA-KIT tool.

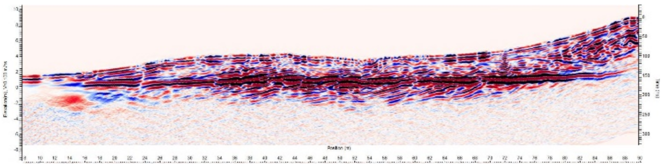

Figure 1. Part of Kaiafas GPR profile reported without vertical exaggeration.

AKNOWLEDGEMENTS

This research was funded by the project "Decision-making tool for the confrontation of coastal erosion and extreme wave events in the coastal zone, in the context of climate change" (MIS 5129417), financed by the Sectoral Operational Programme «Competitiveness, Entrepreneurship and Innovation» (NSRF 2014–2020) and co-financed by Greece and the European Regional Development Fund (ERDF).

European Union
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EPAnEK 2014-2020
OPERATIONAL PROGRAMME
COMPETITIVENESS
ENTREPRENEURSHIP
INNOVATION

ΕΣΠΑ 2014-2020
Partnership Agreement 2014 - 2020

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Coastal Marine Steel Corrosion: the Environment's Influence and In-Situ Monitoring – a Review

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OVERVIEW

At the forefront of exposure, coastal marine steel structures are subjected to the aggressive sea environment either directly in an immersed setting or in the immediate vicinity of the marine atmosphere (via saltwater aerosols). Importantly, this study has initially established that it is vital to distinguish between the coastal and open-sea setting, when discussing marine corrosion, as parameters vary between the two (Table 1). Additionally, steel properties and corrosion types are briefly discussed before the literature's available findings are gathered, in an effort to extract, in a concise and refined manner, the knowledge on the marine environment's effect on steel structures and the field monitoring of the corrosion taking place as a result of these interactions. Furthermore, important deficiencies in the literature have been surfaced and mentioned as opportunities for further research. Examples include the shortage of studies discussing, in isolation, the effect of rainfall on corrosion rate in and the effect of nitrogen oxide pollutants.

PARAMETER	COASTAL/ENCLOSED SETTING COMPARED TO THE OPEN SEAS	EXPLANATION
Salinity	Lower/Higher	Due to dilution by inflowing river flows/Due to increased evaporation. Depending which phenomenon prevails
Nutrients	Higher Concentration	Enriched river influx and agricultural runoffs/Sewage effluents
Biological Activity	Higher	Favorable conditions (nutrients)
Pollution	Higher	Proximity to industrial/agricultural/ domestic activity
Dissolved Oxygen	Lower	Most of the times it is lower (due to increased biological activity consuming oxygen and due to increased salinity)
Temperature	Higher	Proximity to land bodies and enclosed/minimized circulation environment
pH	Higher/Lower	Due to inflowing acidic river waters/Due to acidic pollutants
Calcareous Scale Formation	Higher/Lower Chance to Form	Due to inflowing "hard" ($CaCO_3$ containing) river waters/ Due to inflowing "soft" (low $CaCO_3$ content, low pH) river waters

Table 1. Major Parameters' Variation in Closed Vs Open Seas (Dhanak M.R., Xiros N.I., 2016, Arias H.A. and Botte E.S., 2020, Shifler D.A. 2005)

Finally, related subjects that may contribute to the better understanding of the corrosion mechanisms are brought up. These include, the role of passive layers and the need for their long-term stability further studying, as well as the importance of segregating the corrosion rate in long and short-term segments as it is governed by different parameters over time. Figure 1 below presents schematically this segregation.

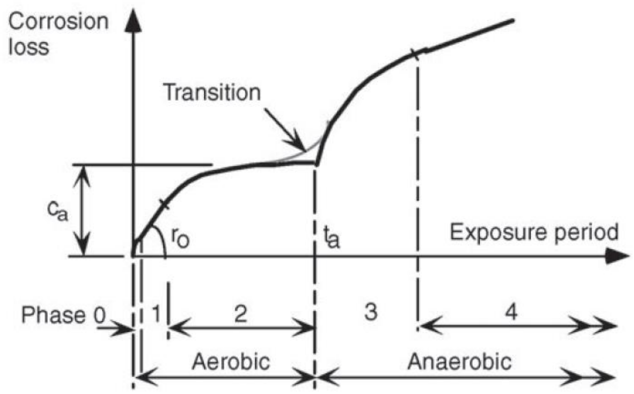

Figure 1. Corrosion Loss Vs Exposure Time (Melchers R.E.,2007)

CONCLUSIONS

Uncertainty is a trait neither agreeable nor desirable by engineering designers in all fields. Nevertheless, oftentimes the effects of uncertainty are restrained by the deliberate use of excess material and a more elaborate-than needed- design, what is known as overengineering. Directly contributing to a safe operational life of steel structures this study aims to gather the environmental factors affecting corrosion rate in a marine setting and the corrosion rate monitoring technologies available to date. Ultimately, it is expected that it will form a reliable basis to be used in anticipating a realistic marine corrosion rate which will aid in avoiding over-engineering practices in newly designed structures but also properly appraising the remaining life of existing infrastructure.

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Monitoring and Analysis of Coastal Eutrophication Using Remote Sensing

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INTRODUCTION

In recent years, marine eutrophication has become a major factor in water bodies' quality control. Agricultural runoff, seawater effluents and intense anthropogenic activities in the coastal areas have amplified the geographic distribution of eutrophic water sites globally (Ménesguen and Lacroix, 2018).

Remote sensing analysis is a fast, cost-effective and near real-time tool to evaluate multiple-water bodies' quality status.

In this study, an effective approach is presented for determining the seasonal distribution of chlorophyll-a in coastal and inland waters.

METHODOLOGY

Daily MODIS Aqua Atmospherically Corrected Surface Reflectance georeferenced images were freely downloaded from NASA's LAADS DAAC website. The analysis expands over a period of almost for 2 decades from July 2002 to 2021 for the selected Study Area with spatial distribution of 500m.

The selected study area of our analysis was Aitoliko Lagoon. Aitoliko Lagoon is situated in the Western Greece and has high ecological importance because it is a wetland protected by Ramsar and Natura 2000 conventions (Gianni et al., 2012). Filed measurements have resulted that Aitoliko Lagoon suffers from eutrophication and anoxic crisis during the spring season (Gianni et al., 2011, Papadas et al., 2009).

Daily georeferenced images had been downloaded, applying RStudio numerical algorithm. Then, specific point stations within the Aitoliko Lagoon were isolated and the remote surface reflectance values were obtained for each spectral channel, for each point station and for a period of almost 20 years.

Statistical data processing is applied to the derived timeseries for each vector of the remote surface reflectance table. The methodology used does not manually exclude possible deriving from aerosols and atmospheric particles. The extreme values are identified and attributed with the constant «c». Negative remote surface reflectance values with no physical meaning are also attributed with the constant «c». Therefore, the new statistical components were found for each vector of the Remote Surface Reflectance Dataset. Then, a new Remote Surface Reflectance dataset is being calculated from the new statistical components without the presence of missing values.

Chlorophyll-a concentration is calculated from the corrected remote surface reflectance values of each point station of the study. According to NASA's Ocean Color approach, the acquisition of chlorophyll-a's concentration requires the values of three spectral channels: red (469nm), blue (555nm) and green (655nm). Two algorithms were created: the OCx algorithm from O'Reilly et al. (O'Reilly and Werdell, 2019) when the concentrations were greater than 0.35mg/m^3 and the Color Index (CI) algorithm as described by Hu et al. (Hu et al., 2019) when concentrations were lower than 0.25mg/m^3. The weighted average was calculated for values between 0.25 and 0.35 mg/m^3.

RESULTS and DISCUSSION

The seasonal distribution of chlorophyll-a concentration of Aitoliko Lagoon describe a eutrophication increase in April until August. In situ measurements of Gianni et al and Papadas et al. (Gianni et al., 2011, Papadas et al., 2009) have concluded to the same result.

Aitoliko Lagoon is eutrophic since it receives the wastewater from Aitoliko town and irrigation waters from the catchment.

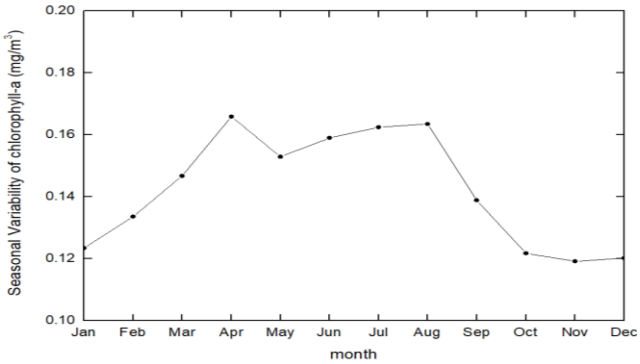

Figure 1. Seasonal variability of chlorophyll-a (mg/m^3).

The results of this study could help stakeholders to identify potential months for restoration and water treatment. The sporadic in situ measurements do not offer the opportunity to evaluate the change of chlorophyll over time. Remote sensing chlorophyll-a evaluation offers a new tool for the management plans for coastal areas, as well as lakes and reservoirs.

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Integrated Observatory System for Managing Coastal Erosion Risk Due to Climate Change using Earth Observation Data: a Project by the Managing Authority of the Central Macedonia Region, Greece

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SCOPE OF RESEARCH

To address the negative impacts of climate change on natural disasters and hazards, the Managing Authority of the Central Macedonia Region has funded a project to create a digital Observatory that enhances knowledge on hazard exposure and vulnerability related to coastal erosion.

RESEARCH PROJECT DESCRIPTION

The project used advanced algorithms, models, Earth Observation, and in-situ data in three thematic phases to evaluate the current state of the coastal area and propose alternatives for risk management. Phase A focused on designing a web GIS application to host the observatory, its services, and the resulting datasets. Phase B involved creating algorithms and tools to calculate the necessary indicators, and Phase C focused on evaluating the current state of the coastal area and proposing alternatives for risk management.

METHODOLOGY

Throughout the project, the spatial databases were continuously re-evaluated to accommodate the digital products created by applying specialized algorithms. These algorithms processed optical images from the Sentinel-2 and Landsat-8 satellites to create timeseries of multiple indicators, such as Chl-a and coastline alterations. Additionally, Sentinel-1 SAR acquisitions were used to extract a low-resolution Surface Deformation Rates model and satellite altimetry observations from the Cryosat-2, Jason1/2/3, SARAL and Sentinel-3a/3b missions were used to monitor Sea Level Anomalies and variations in Sea Surface Temperature. In-situ observations of the coastal area were also conducted, utilizing techniques such as GNSS, UAV mapping, and echo sounding to calculate high-resolution models of the topography and bathymetry.

RESULTS

The obtained indexes and products are updated frequently, and simulations have been conducted to assess the vulnerability of the coastal area to tidal waves. Additionally, a tool has been developed that can determine flood mapping passively for different sea level rise scenarios, aiding local authorities in making decisions and evaluating alternative strategies for the development of the coastal zone.

Carrying Capacity Indicators in Tourism – the Case of the Island of Paros Coastal Zone

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ABSTRACT THEME

Many researchers have studied the challenges concerning the carrying capacity of tourist destinations. Carrying capacity has been defined as the ability of an ecological system to sustain the development of human activities without negatively impacting the ecosystem services inherent within the system. It is a common belief that the carrying capacity approach has proved to be both significant and functionally supportive of tourist destination sustainable management. Considering the challenge of sustainable growth, it is important to emphasize that tourism causes various negative impacts that may risk long-term growth and that overlooking the interdependence between the concept of carrying capacity and sustainability of tourism growth, will most likely, exacerbate the many problems that arise in areas of unique socio-cultural and ecological value. Previous research has developed specialised measurement instruments and indicators, as well as a comprehensible methodological guide for their use, in order to estimate the carrying capacity and limits of a tourist destination. Many Greek islands and coastal areas have been studied in an attempt to identify the factors influencing a tourist product and its ecological, social and economic sub-systems, including infrastructure, environmental characteristics and tourism entrepreneurship. The above were applied to Paros, a Greek Island in the central Aegean Sea, which hosts a many as 500.000 tourists per year, in an attempt to further involve local societies and stakeholders in addressing and understanding the impacts on existing non-renewable resources, the transport infrastructure and primary production. This endeavour aims to design a comprehensive, diverse and socially integrated sustainable tourism strategy policy for the island of Paros.

Towards a Digital Twin for Marine and Maritime Activities: The ILIAD Project Framework

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INTRODUCTION

The concept of Digital Twin was firstly introduced in 2002 by M. Grieves from the University of Michigan, presenting the formation of a Product Lifecycle Management (PLM) center, in which all elements of the Digital Twin were introduced. Such sub-components are: the real-physical space, the virtual-digital space, the link for data flow from real space to virtual space, the link for information flow from virtual space to real space and the virtual sub-spaces. This meant that there was a mirroring or twinning of systems between what existed in real space to what existed in virtual space and vice versa. The technology of Digital Twin emerged in the framework of Industry 4.0 coupling basic IT technologies like cloud computing, Internet of-Things (IoT), Big Data, and Machine Learning (ML).

Following that concept, we may define a Digital Twin as a virtual/digital representation, serving as the real-time digital counterpart of a physical object or process. Digital twins are the result of continual improvement in the creation of product design and engineering activities. Presently, DTs are based on the following elements:

- Smart Sensors for RT data collection
- IoT systems for data transfer and data feeds
- Decentralized or centrally-stored data in cloud servers
- High resolution/high in accuracy simulations to virtual copies
- Interactive platforms to display RT 3D/4D spatial-temporal data
- ML, AI and software analytics
- Augmented reality (AR) systems, as visualization technologies
- Optimization processes for machines, products, procedures, services
- Monitoring, diagnostics, prognostics.

DIGITAL TWIN OF THE OCEAN

Limited literature currently exists on the topic of development and implementation of Digital Twin of the Ocean (DTO). Jiang et al. (2021) developed a Digital Twin acting as a fast and accurate surrogate of the coastal ocean aiming to minimize the coastal flood risk under accelerating sea level rise. Corraddu et al. (2019) proposed a data-driven DT to estimate the speed loss of a cargo carrier due to marine fouling at the hull and propeller, leveraging on the large amount of data collected from the on-board sensors. Collected data (GPS lat and lon, pitch, roll, yaw, fuel consumption, fuel temperature and density, propeller speed, ship draft (fore, aft), sea depth, wind speed and direction, sea water temperature, etc.) were fed on Deep Extreme Learning Machines to detect during real operations a deviation in the speed performances (with respect to the ones achievable with clean hull and propeller), and consequently to identify the extension of the marine fouling phenomena. Schirmann et al. (2019) presented a digital twin for ship motion and estimation of structural fatigue due to wave response.

THE ILIAD MARINE AND MARITIME DTs

ILIAD is developing a series of Pilot DTs for selected marine and maritime sectors to support Industry 4.0, to benefit from IoT data collection and transfer, to leverage from Big Data analysis and AI tools, and produce standardized and accredited data, in accordance to the FAIR principle.

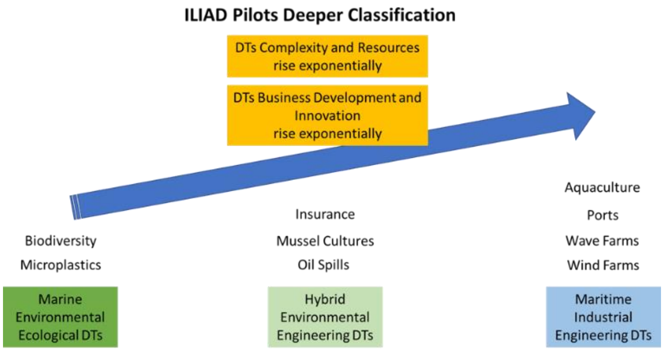

Figure 1. ILIAD Pilot DTs classification and characteristics of each category.

Focusing on the individual components comprising the DT, we may find that:

- The one-way DTs, like the marine ecological DTs, acting as Data Integrators.
- The hybrid DTs, in which the loop is partly achieved. These DTs act like Simulators, with increased RT data transfer and moderate citizen science engagement.
- The maritime industrial and engineering DTs, like the ports, the wind and wave farms and the aquaculture facilities. These DTs appear as ‘two-way’ Control Systems, with a closed continuous loop, in which data are integrated and simulations play a key role in system’s performance optimization.

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Advancing Image Analysis Practices for Condition Assessment of Port Infrastructure with GIS Applications

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INTRODUCTION

Ports are catalysts for the economic growth of societies at both national and international levels. However, they are challenged to maintain the performance of their infrastructure under the influence of various stressors (e.g. harsh marine environment, aging, climate change impacts etc.). Hence, powerful management strategies are required to ensure the structural and functional capacity of port infrastructure by applying monitoring and condition assessment practices.
Regarding port concrete infrastructure, condition assessment encloses crack detection. Currently, there is a growing trend in utilizing Unmanned Aerial Vehicles' (UAVs) imagery for identifying cracks in concrete surfaces. Indeed, Red, Green and Blue (RGB) images collected by cameras mounted on UAVs are further analyzed with image processing methods to extract information about cracking (Gupta & Dixit, 2022). Considering this, the present research seeks to advance crack detection in port concrete infrastructure by combining image analysis and GIS functionalities.

METHODOLOGY AND RESULTS

Crack detection in concrete infrastructure is usually performed by applying edge detection algorithms, thresholding/ binarization methods and morphological operations (Dorafshan et al., 2016) with programming languages. Considering this, the methodology proposed herein encloses: a) existing practices for concrete crack detection, properly adjusted to address challenges impeding image processing for port concrete infrastructure (e.g. the presence of passengers, vehicles, shadows, surface markings, etc that create a noisy and disturbed background in UAV images), and b) GIS applications to elaborate with analyzing orthophotos (i.e. the georeferenced output generated by applying photogrammetry methods at UAV imagery). The major steps of the above synergy are presented below:

1. Clipping orthophotos based on the optimal number of RGB georeferenced images required for image processing. Given a specific grid, each concrete slab is divided into cells (RGB raster images) with GIS tools, thus creating a new raster dataset.
2. Conversion of RGB image cells to grayscale images by applying median filters with python and/or GIS tools.
3. Application of widely used filters for image binarization (such as Sauvola or Niblack) with python packages.
4. Post-processing of the binary images with morphological operations to connect crack segments and remove non-related to crack pixels with python packages.
5. Vectorizing/polygonizing binary images to quantify cracking with GIS tools.

The methodology was applied at the concrete wharf of the domestic-ferry domain of Lavrio port located at the southeastern tip of Attica, Greece. The original orthophoto generated by UAV data analysis was further processed (steps 1 and 2, as shown in Figure 1a) to obtain a dataset of binary raster images (steps 3 and 4, as shown in Figure 1b). Once vectorizing/polygonizing was complete (step 5), existing cracking was satisfactorily detected (Figure 1b).

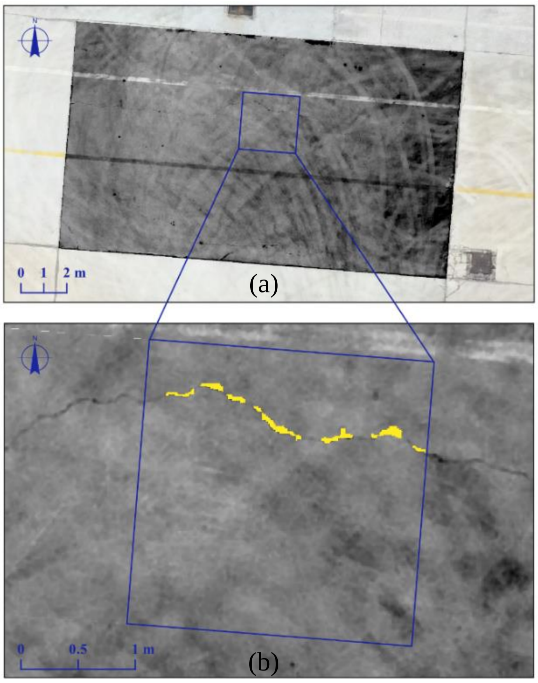

Figure 1. Python and GIS-based analysis of a specific concrete slab image of the wharf of the domestic-ferry domain of Lavrio Port (a) to enable crack detection for a given grid cell (b).

CONCLUSION

Identifying, mapping and quantifying the cracking of port concrete infrastructure is a demanding task. Image analysis techniques enhanced with GIS applications indicated satisfactory results. However, further research is required to improve image analysis precision.

ACKNOWLEDGMENTS

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Expansion of Pier 6 of the Port of Thessaloniki

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INTRODUCTION

The port of Thessaloniki is one of the largest ports in Greece. The port's land zone occupies a total area of approximately 1,550,000 square meters and spans a length of approximately 3,500 meters. It comprises a 6,150-meter-long quay, 6 piers, administrative and technical support buildings, warehouses and shed, special equipment and other installations. The geographic location of the Port of Thessaloniki and its excellent road links and train connections makes it the largest transit-trade port in the country, and it services the needs of approximately fifteen million inhabitants of its international mainland. The expansion of Pier 6 has always been considered necessary for the Port to fulfill its role.

GENERAL DESCRIPTION OF THE PROJECT

Following the Concession Contract, Thessaloniki Port Authority S.A. (THPA S.A) holds the responsibility of completing the Pier 6 Expansion. The detailed design of this work was carried out by ROGAN ASSOCIATES, as part of the DPM's JV (Hill Intl.–Rogan Associates), in collaboration with COWI and GR8, which includes:

- Extending quay 26 of Pier 6 by 513m southwards, of which 470m will have a functional berthing depth of at least -16.80m (LLW) or -17.70m (MSL).
- The new quay wall will be constructed with the precast floating RC Caisson technique. Steel inclusions will further reinforce the foundation of the quay wall.
- Construction of a Yard with width of 306.5m with reclamation.

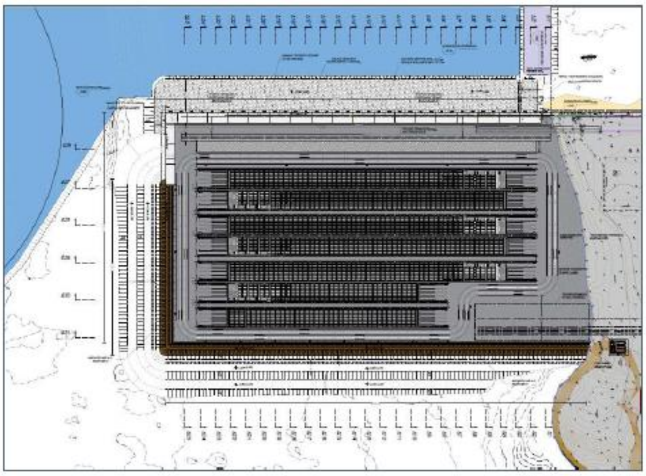

Figure 1. General layout of Pier 6 proposed extension.

- Construction to the south and eastern part, for the wave's protection, revetment from rock armor.
- For the construction of the reclamation area, soil improvement methods will be applied to improve the subsoil properties, which will include (a) removal of the surface soft clay layer and replacement with coarse-grained materials and (b) installation of prefabricated vertical drains (PVDs).
- Construction of deep foundations, of the rear crane rail, with piles, so as to accommodate Ship - to - Shore (STS) type cranes.
- Dredging the port channel and maneuvering area to accommodate the safe approach and mooring of the maximum size design ship at the harbor.

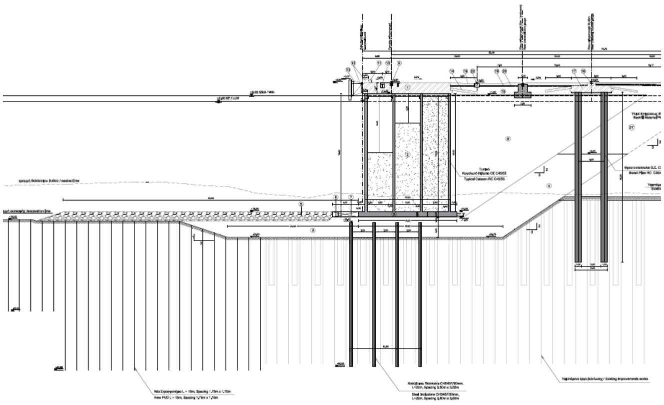

Figure 2. Typical Cross-section of the quay wall.

GEOTECHNICAL PARAMETERS

For the estimation of the geotechnical parameters of the projects' foundations a thorough Geotechnical Survey was conducted, consisting of four (4) offshore drillings (of which one reached a depth of 80m below seabed) and six (6) penetrometer tests (CPTs).

DESIGN SHIP

The requirements of THPA S.A., concerning the specifications of the design ships are as follows:

- Ultra Large Container Vessel (ULCV) - carrying capacity 24,000 TEU.
- Smallest design ship: Feeder – carrying capacity 1,500 TEU.

SOIL IMPROVEMENTS CONCEPT

Due to the fact the project lays on silt-clay layers, thus subject to long-term settlements, a limited upper zone will be improved to act as a buffer zone. Within this zone, settlements will be completed before construction of the permanent top structures and the operation works. The remaining long-term settlements, due to deeper non-improved silt-clay layer, are expected to be mostly uniform.

DYNAMIC ANALYSES

Two-dimensional dynamic soil-structure interaction analyses were performed to estimate the earthquake-induced horizontal and vertical displacements of the caisson and the crane supports and kinematic demands in piles.

Creation of a Double Berth Jetty for Small Scale LNG Carriers & Barges in Revithoussa Island, Greece – a Multipurpose Terminal

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INTRODUCTION

Poseidon Med II project aimed at bringing the wide adoption of LNG as a safe, environmentally efficient and viable alternative fuel for shipping and help the East Mediterranean marine transportation propel towards a low-carbon future.

The project, which was co-funded by the European Union, involved three countries Greece, Italy and Cyprus, six European ports (Piraeus, Patras, Limassol, Venice, Heraklion, Igoumenitsa) as well as the Revithoussa LNG terminal. The project brings together top experts from the marine, energy and financial sectors to design an integrated LNG value chain and establish a well-functioning and sustainable LNG market.

The present study, assigned to Rogan Associates by Asprofos, is based on the outcomes of the Conceptual Design performed in the framework of "Poseidon Med II" project. It aims to the production of a FEED Design and of all appropriate documentation necessary for application, at a later stage, by an EPC Contractor who shall perform the detailed engineering, construction and pre-commissioning of a New Small Scale LNG Infrastructure at Revithoussa Terminal of DESFA, adequate of accepting LNG carriers with capacities ranging from 1.000 m3 up to 20.000 m3.

PROJECT DESCRIPTION

The project aims at designing a comprehensive value chain for the use of LNG as marine fuel in the shipping industry and develop a sufficient infrastructure network of LNG bunkering, including the development of a LNG transportation, distribution and supply network in Revithoussa island.

This paper briefly presents aspects of the design of the necessary marine infrastructure required for LNG operations of small-scale LNG Carriers and barges, at an area north of Revithoussa island, that will serve the aforementioned scope. The required FEED studies were prepared on the basis of current European Directives as well as the National legislation. Prior to the FEED study, a number of supporting studies was carried-out. Moreover, an Environmental Impact Assessment was performed.

PROJECT OVERVIEW

The area north of Revithoussa island for the creation of the jetty has been based on previous Site Selection study. The necessary infrastructure foreseen for this Project includes the following:

1. Offshore Marine Works: Double Berth Jetty for the loading/ unloading operations of small-scale LNG Carriers and barges.
2. Breasting and Mooring Dolphins.
3. Cryogenic pipelines.

Various E/M installations necessary for the operation of the SSLNG infrastructure.

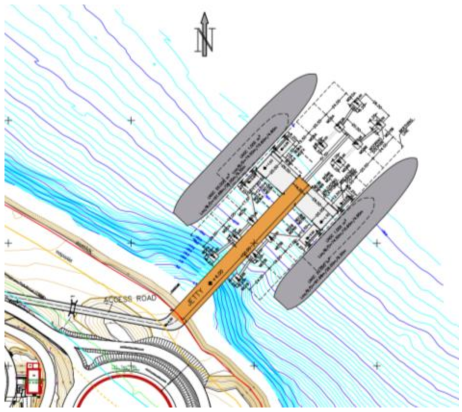

Figure 1. Layout of Harbour Works.

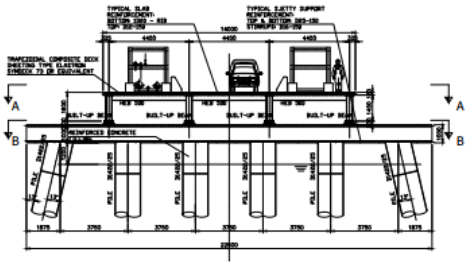

Figure 2. Trestle's typical cross section.

MARINE INFRASTRUCTURE

A new offshore Jetty Facility on piles, having an overall length of about 150m was designed along the North-East side of Revithoussa island.

The jetty will be perpendicular to the coast, allowing the berthing of two (2) LNG carriers/ barges at the same time. Minimum sea depth of 11m is guaranteed to host LNG carriers with capacity up to 20.000 m3.

The Jetty consists of a trestle on piles, of length 150m and width 14m, two (2) loading platforms, one on each side of the trestle, each of dimensions 29m X 20m, four (4) Breasting dolphins, each of dimensions 17,5m X 8,2m, and twelve (12) mooring dolphins, six (6) on each side of the jetty each of dimensions 6,20m X 6,20m.

PERFORMED STUDIES

The studies performed in the framework of the Project are: HAZID, HAZOP, Geological-Geotechnical, Met-Ocean, Mooring, Civil & Structural Studies, Safety & Fire-fighting, Process, Piping, Electrical, Instrumentation & Control Design, Environmental Impact Assessment including Baseline studies.

Numerical Modelling of Dredged Material Dispersion at Dredging and Disposal Areas

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INTRODUCTION

Numerical modelling using sediment transport models (coupled to hydrodynamics and wave models) can be used to predict the ecological pressure caused by dredging activities (through increases in suspended solids, sediment smothering and light reduction). During dredging operation, and the disposal of dredged sediment in open sea, the resulting turbidity plume can decrease light for photosynthesis, interfere with fish respiration and feeding, cause discoloration of normally clear surface waters, reduce oxygen levels, and release adsorbed pesticides, herbicides, toxic metals, or synthetic organic compounds into the water column. The magnitude of sediment concentration should be placed in context with other sediment resuspension events or sources, (i.e. waves, currents, river flow, etc.).

The goal of the Numerical Modelling is to improve the prediction of the transport and diffusion of dredge-generated sediments by developing an improved understanding of key physical processes that control the extent, intensity and duration of sediment plumes.

This paper presents a numerical model for simulating the advection, diffusion, and dispersion of dredged material. The model is applied in both dredging and disposal areas by simulated dredging-induced sediment resuspension during excavation. Finally, morphology evolution in the disposal area is estimated.

SEDIMENT SUSPENSION DURING DREDGING OPERATION

During dredging, in the suction area, especially when a cutting head is used, sediment re-suspended and it is transported, diffused, and dispersed in the marine environment by currents. At the same time, through the overflow water of the temporary storage tank a part of the incoming sand will not settle during loading in the hopper but will re-enter in the water column of the wider dredging area.

If a trailing suction hopper dredger is used, the net concentrations of resuspended sediments C_r (kg/m^3) induced by cutterhead dredges is given by (Hayes et al., 2000):

$$\frac{C_r}{\rho 10^{-6}} = F_F\, F_D \left(\frac{V_s}{V_i}\right)^{2.848} \left(\frac{V_t}{V_i}\right)^{1.022} \quad (1)$$

where V_s = swing velocity at the tip of the cutter (m/s); V_i = suction intake velocity at the cutter blades (estimates based upon observed flow rates and assuming an elliptical cutterhead surface) (m/s); and V_t = tangential velocity of the cutter blades at the top of the rotation relative to the surrounding water (m/s), ρ = density of waters above the mudline (g/cm^3); F_F= regression parameter that accounts for the cutter size and median grain diameter; and F_D = regression parameter that accounts for the thickness of cut relative to the cutter diameter (Hayes et al., 2000).

The cumulative concentration of suspended sediment due to re-entering varies with time: at the beginning of dredging, it is of the order of 0% of the amount of the incoming sediment, while at the end when the hopper is filled it can even reach 40% of the incoming sediment (Van Rhee, C., 2002).

QUASI 3D HYDRODYNAMIC AND ADVECTION-DISPERSION MODEL

A quasi-3D hydrodynamic model is used to predict wind induced current velocities. The model equations are derived from Navier-Stokes equations, after the assumption of hydrostatic pressure distribution and constant over the depth eddy viscosity. By assuming constant over the depth vertical eddy viscosity coefficient a parabolic over the depth horizontal velocity distribution is obtained according to Koutitas (1988). Alternatively, a parabolic distribution of the vertical eddy coefficient leads to a double-logarithmic velocity profile including both the surface and bottom sublayer (Tsanis, 1989, Wu and Tsanis, 1995). Thus, a quas-3D simulation is obtained.

Wave induced currents are also described through by including radiation stress terms.

The sediment concentration is obtained by solving the advection–diffusion-dispersion equation, which has the form:

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} + (w - w_f)\frac{\partial c}{\partial z} = = \nu_h \frac{\partial^2 c}{\partial x^2} + \nu_h \frac{\partial^2 c}{\partial y^2} + \nu_t \frac{\partial^2 c}{\partial z^2} + q \quad (2)$$

where c is the sediment concentration u, v and w are the current velocities, w_f is the fall velocity of the sediment, ν_t is the vertical diffusion coefficient, ν_h is the horizontal eddy viscosity given through the Smagorinsky eddy parameterisation, q is a source term which is used to insert the sediment into the system due to dredging, according to eq. (1). Sediment suspension due to current and waves and deposition are introduced through bottom boundary conditions, i.e. "gradient" bed b.c. or "concentration" bed b.c.:

$$\nu_t \frac{\partial c}{\partial z} = E - D, \quad E = w_s\, c_e, \quad D = w_s\, c_{bottom} \quad (3)$$

$$c_{bottom} = \frac{0.01 D_f}{g(\rho_s/\rho - 1)} \quad (4)$$

where E, D are the erosion and depositional rates respectively, D_f is the work done by bottom friction, c_{bottom} is the bed concentration, c_e is the equilibrium concentration at the reference (bed) level and ρ and ρ_s the water and sediment density respectively.

Bed evolution in the disposal area is calculated by solving the equation of the conservation of sediment transport.

MODEL APPLICATION

The model is applied to Thermaikos Gulf for the prediction of for tracking of dredged material both in dredging and disposal areas.

Considering a dredging area located in the port of Thessaloniki region, the suspended sediment concentrations during dredging operation area is shown in Figure 1. In the same Figure, the area of the sediment deposition on the seabed is also shown. The wind conditions are NW and 9Bf. Following eq. (1), the source term in eq. (2) is estimated to be q =500 kg/s.

At the dredging area the sediment plume is transferred towards the port of Thessaloniki area. Consequently, under the above wind conditions dredging operations should be avoided.

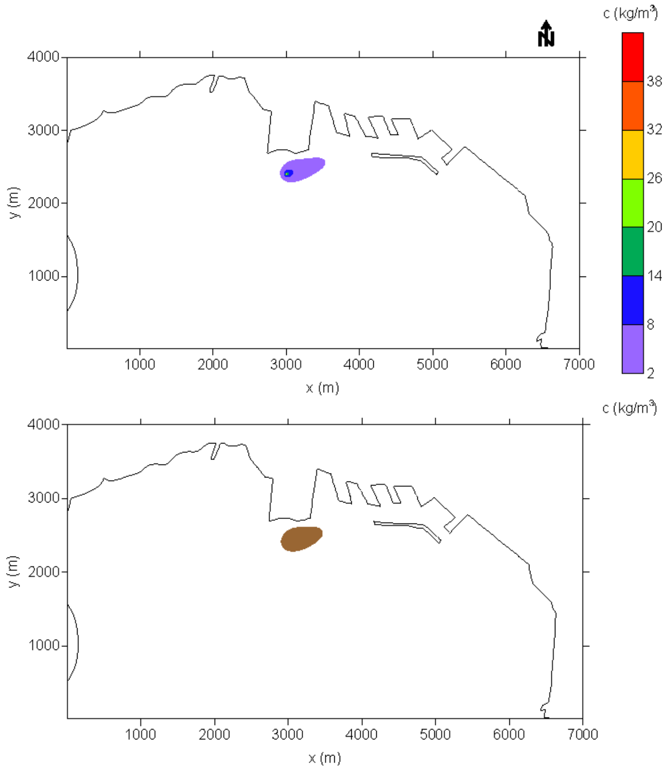

Figure 1. Suspended sediment concentrations at the dredging area (above) and area of the sediment deposition at the seabed (below).

By considering that 20000 kg of sediment are disposed within 10 min, in the centre of Thermaikos Gulf, under the same wind conditions, the calculated concentration as well the sediment deposition area at the seabed is shown in Fig. No significant advection-diffusion-dispersion of the sediment plume is predicted, indicating the correct choice both the time (which could be related to the predicted wind conditions) and the disposal area.

CONCLUSIONS

By using quasi-3D hydrodynamic and advection-diffusion-dispersion numerical models the time of the dredging operations as well as the time and the area of the disposal can be estimated. In this way the evaluation of the environmental impacts and the management of dredging operations could be supported.

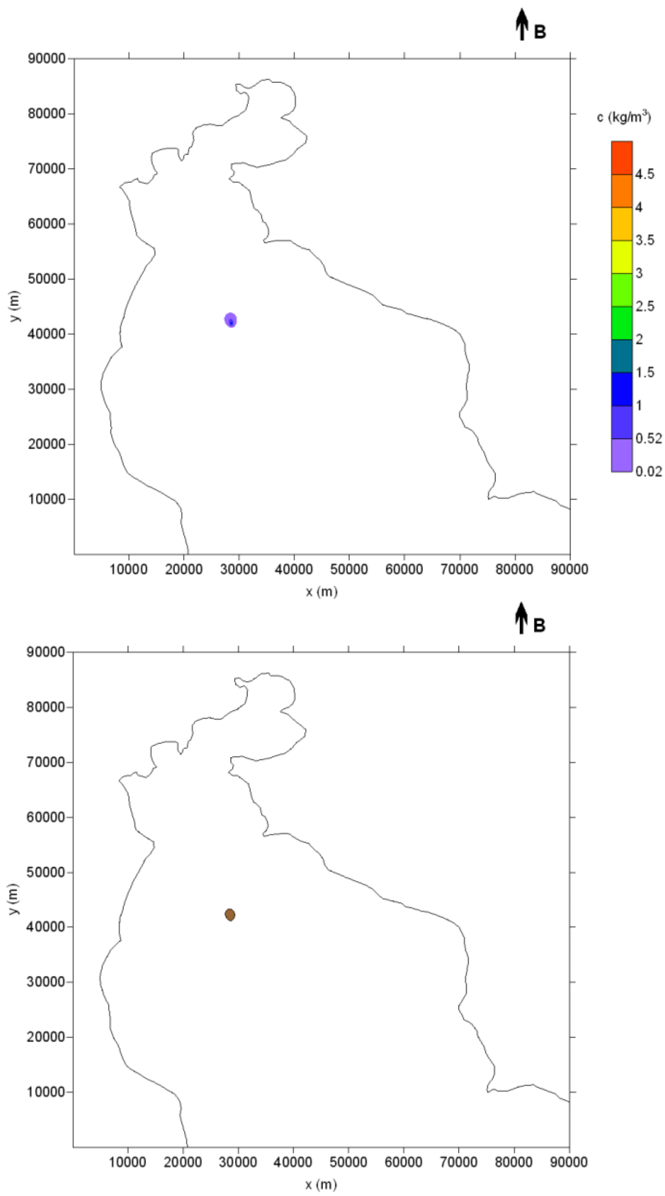

Figure 2. Suspended sediment concentrations at the disposal area (above) and area of the sediment deposition at the seabed (below).

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Assessing the Impact of Climate Change in Wave Agitation for the Port of Piraeus

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INTRODUCTION

Ports are vital links in the chain of maritime transportations and are essential for the global trading network. In parallel, they constitute long-lasting and critical infrastructure. Given the crucial role of ports, their exposure to climate change related hazards poses a considerable threat to both their infrastructure and operations. Taking advantage of the rapidly grown and publicly available metocean databases, this research aims to investigate, through numerical modelling, the impact of increased extreme wave events, due to climate change, in the wave disturbance of the Port of Piraeus, Greece.

MATERIALS AND METHODS

To perform a detailed evaluation of the wave agitation inside the port of Piraeus, hourly changing timeseries of wave characteristics were extracted from the Copernicus Marine Service (CMS) and Copernicus Climate Data Store (CDS) for the following time periods:

- Hindcast offshore wave data for 1993-2021 from CMS,
- Forecast offshore wave data for 2040-2100 according to Representative Concentration Pathway (RCP) RCP 4.5 from CDS,
- Forecast offshore wave data for 2040-2100 according to RCP 8.5 from CDS.

Comparative tables of mean annual wave characteristics with the respective frequencies of occurrence were produced from all the three different offshore wave data timeseries by dividing the wave climate in 12 directional sectors and wave height groups of 0.5 m intervals. Given the orientation of the port infrastructure, it is determined that waves approaching from the S, SSW, WSW, W and NW sectors are able to create wave agitation and disturb port operations. The wave propagation simulations were carried out with the Maris-HMS (Scientia Maris, 2022), hyperbolic mild slope wave model.

RESULTS

An increase of the maximum wave heights in the dataset, propagating from the S sector, as well as a raise in the frequency of occurrence of extreme sea-states were observed in both RCP scenarios compared to the hindcast data of CMS. Furthermore, an increase in both the presence of extreme wave events and frequencies of their occurrence is noted for the SSW and WSW sectors. The latter showcases possible future issues, since waves propagating from these sectors are potentially harmful for port operations due to the port's orientation. In Figure 1, comparative results for the highest wave of CMS (H_s=0.91 m) and RCP 8.5 (H_s=2.14 m) from the WSW sector, utilizing the Maris-HMS model are shown. Conducting the simulations for each wave group for the 5 directional sectors previously mentioned, a significant percentage increase on wave agitation levels, compared to the hindcast simulations (from CMS) was detected in the port basin, potentially compromising port operations.

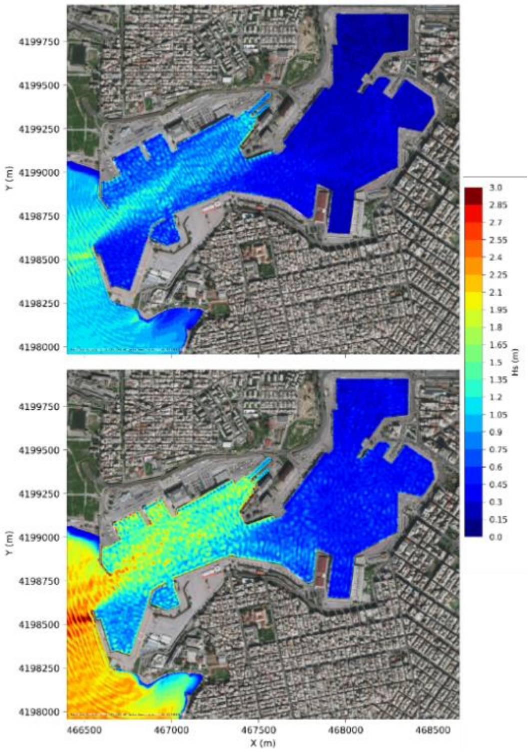

Figure 1. Significant wave heights for the highest wave of CMS (top) and RCP 8.5 (bottom) propagating from WSW sector.

CONCLUSIONS

The findings hereto reported demonstrate the potential vulnerability of the Port of Piraeus in relation to wave action and its alterations, in the context of climate change. Besides the indications of future vulnerability, the results are useful to further determine the criticality of assets and design pathways to improve the port's resilience.

ACKNOWLEDGMENTS

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Contemporary Types and Models of Private Sector Involvement in Ports

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INTRODUCTION

Seaports, as important nodes in maritime transport, have a significant influence on the economic, social, and environmental development of countries on a local, regional, and national level. A changing economic environment produced by the globalization of production and distribution, changing forms of cargo transportation, technological breakthroughs, and many more issues, ended a long period of state-controlled (public) port governance models in most countries. To adapt to the new context, many governments entered a period of port reform, changing applicable governance structures. Most reforms devolved management responsibilities and, to a lesser extent, transferred responsibilities associated with port ownership to newly created or existing private corporate entities. Private sector participation in ports has been increasing continuously ever since either through privatization or most commonly through public-private partnerships (PPP). Public authorities are embracing PPP to overcome budgetary constraints, to compensate for their lack of expertise in operations, to boost economic growth and to attract foreign direct investments (FDIs).

SCOPE OF STUDY

This paper aims to discuss the reasons behind the implementation of Public-Private Partnerships as well as the various forms in which these partnerships have taken place within the port industry. A detailed analysis will be presented regarding the characteristics and applications of each PPP model with emphasis to concession agreements.

Concessions are the most common form of Public-Private Partnerships in the port industry. A port concession means that the port authority grants rights over specific port land for a certain period of years for an agreed fee. Different concession types have been implemented with the most common being the landlord model. The relevant issues related to the prevailing concession types and models as well as the content of concession agreements will be presented.

Smart and Green Ports

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INTRODUCTION

The rapid growth of world trade and the progress of digitization have led to the need for more complex infrastructures to support the increased amount of cargo and the adaptation of logistical support to the new data. At the same time, tackling climate change is one of the most important challenges facing the global community today and ports, which are major sources of pollution, must contribute to the protection of the environment. In this regard, smart ports through the use of technological innovations to enhance port activities and services aim to increase the competitiveness and economic viability of an area, while, at the same time, help reduce greenhouse gas emissions and energy savings.

PURPOSE

The purpose of the present MSc thesis is to analyze on which the construction and operation of a smart and green port should be based, as well as ways to make the port industry more environmentally friendly.

METHODOLOGY

Firstly, we present the definitions of smart and green ports. We examine the contribution of information and communication technologies to the development, organization and management of ports, as well as the difficulties that need to be eliminated in order to move to the digital age. Following that, we present examples of ports that have effectively integrated digital technologies into their operations. In addition, we analyze the need to implement environmentally friendly policies, energy management and find alternative fuels for maritime transportations, so that the port and shipping industry contribute substantially to the protection of the environment.

EVOLUTION OF PORTS: PORT GENERATIONS

Several attempts have been made in the literature to classify ports into typologies and analyze their role and functions, without however a commonly accepted framework, due to the complexity and heterogeneity of ports.

In 1992, at the United Nations Conference on Trade and Development in Genoa, the first systematic attempt to categorize ports is made → a comprehensive approach to the characteristics and evolution of the port industry that led to the classification of different types of ports into categories, the "Port Generations" .

In the modern environment, where the port industry sector is faced with continuous challenges, such as structural changes in the trade pattern, natural disasters, terrorist attacks, etc., while at the same time the pursuit of environmental protection and sustainable development and the rapid development of information technology dominate , the framework of the four port generations is not sufficient to reflect the functions of ports required by the needs of their users and the community.

The fifth generation ports integrate the service functions of the ports of the previous four generations, while at the same time adapting to the innovative trend of smart and green technology, emphasizing the integration of advanced IT and telecommunication technology systems and environmental protection.

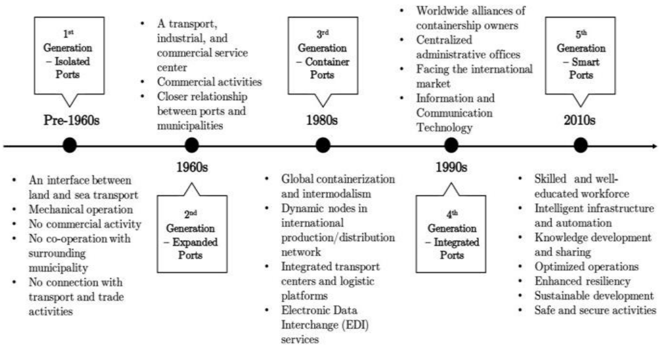

Figure 1. Evolution of ports over the years,

ATTENTION

Finally, to address the issue more effectively, proposals are made on how the Greek ports could utilize their geophysical wealth and integrate the new smart and green technologies in order to achieve sustainable development and protection of the environment.

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Piraeus Port Authority S.A. and Thessaloniki Port Authority S.A. before and after the Privatization

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INTRODUCTION

The two largest Greek Ports of Piraeus and Thessaloniki, managed by Piraeus Port Authority S.A. (PPA) and Thessaloniki Port Authority S.A. (ThPA) respectively, were privatized by transferring the majority of their shares in private compagnies. The procedure was undertaken and accomplished by The Hellenic Republic Asset Development Fund S.A. (HRADF).
In the present paper were analyzed volumes, revenues and investments from both ports before and after the privatization and calculated indicators to estimate their performance.

THE PRIVATIZATION PROCESS

In 2001-2002 the managing bodies of the two Ports became Public Limited Compagnies (S.A.) and their shares are traded on the stock exchange.
The Concession Agreement (C.A.) of Piers II and III with Cosco Pacific Ltd and PPA entered into force on 1/10/2009. Under the name Piraeus Container Terminal (PCT) the new company will operate Pier II and will construct and operate Pier III of Piraeus Port. The eastern quay of Pier III finished in 2016 and the western quay in 2018.The new C.A. between the Greek State and PPA included the process of a majority stake (51%) transferred to Cosco Shipping (Hong Kong) Limited, which completed on 10.08.2016 with a mandatory investment plan of 293.783.800 € in the first period of 5 years, (including infrastructure and equipment). From this plan the cruise terminal is not yet constructed. An additional 16% of shares were transferred to Cosco in 2021.
The C.A. between the Greek State and ThPA included the process of a majority stake (67%)transferred to «South Europe Gateway Thessaloniki (SEGT) Ltd» which completed on 18.3.2018 with a mandatory investment plan of 180.000.000 € for the first 5 years including infrastructure and equipment. Investments in equipment are in progress and the extension of Pier 6 is scheduled. In 2020 ThPA established a subsidiary dry port based in Sofia, Bulgaria and named "ThPA Sofia Ead".
For both ports, the concession fee was set as a percentage of the total consolidated revenue of each Company at 3.5%.

ANALYSIS OF DATA

For the purpose of this paper statistical data from both ports were collected and analyzed. PPA revenues are from (PPA, 2023): Coastal shipping, Cruise, Car terminal, Ship Repair, Containers (Pier I), Subconcession (Piers II and III) and secondary sectors. Revenues for ThPA (ThPA,2023) are from Containers, Coastal Shipping and Cruise, General Cargo and land rentals. At Fig. 1 the total revenues of both Ports from 2003-2021 are presented. At Fig. 2 the containers throughput, for Pier I, PCT (Piers II&III), PPA (total) and ThPA is presented. They are also estimated the mean Terminal Handling Charges for PCT, PPA and ThPA respectively, and others indicators concerning all the involved sectors.

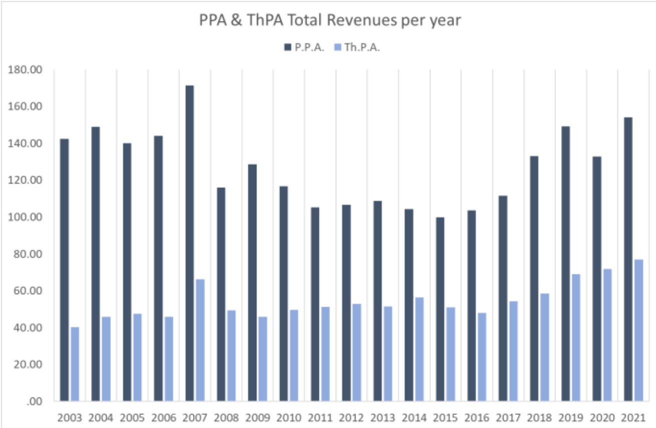

Figure 1. Total revenues per year for PPA and ThPA

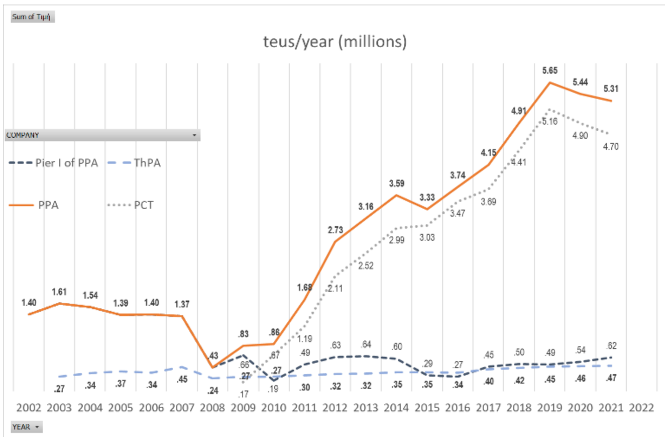

Figure 2. Annual TEU'S handled by PPA (total), PPA (Pier I), PCT and ThPA

CONCLUSION

For PPA the best year for the revenues was 2007, just before the world financial crisis of 2009. For ThPA 2007 was the best year before the C.A. The Covid-19 crisis in 2020 seems to affect PPA, but not ThPA.
PPA via PCT presents a significant increase in annual TEU's throughput, after the privatization, especially after the completion of Pier III. The sector of ship repair presents also increases after the completion of new investments.
ThPA after the privatization shows a dynamic growth trend, even before the completion of the investment plan and good financial results

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Revisiting Port Regulatory Governance & Substance: Towards a Holistic Supply Chain Approach

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Abstract-in-Depth

In the context of globalization and of dispersed production and consumption, modern maritime transport along with ports are the backbones of international trade, as well as a key contributing factors in the economic growth and development of countries around the globe.

To adapt to the novel characteristics of the industry (containerization, lack of public funds etc.), liberalization of the port industry and introduction of competition was promoted as the solution which would render the production of the port product and services more efficient and more effective.

The port devolution wave that followed on a global scale, through various privatization schemes led eventually on the one hand to the establishment of various novel port governance models while on the other to the shift of power from the public to the private sector. While ports became prominent fields of private investment, port managing bodies, i.e. port authorities in the majority of occasions remained public, however their functions as well as their roles within the port were reconfigured.

The globalization of players within the port industry and the concentration of more and more terminals in the investment portfolios of a handful of operators, as well as the interconnection of the latter through subsidiaries, both with liner carriers as well as with companies providing hinterland and value-added services, brought about a reorganization of the port services market while reshaped the relations between the members of the supply chain.

These organizational developments, however, did not initiate the necessary changes to upgrade the regulatory framework within which ports operate, making the existing framework ineffective and outdated. As such, it has been increasingly challenging and difficult for Port Authorities to implement and enforce effective tools to regulate global players at a local port level. These reasons raise both at the port level and at the level of the supply chain as a whole, issues for the re-examination of the role and effectiveness of the regulatory function.

While the effects from the enforcement of port economic regulations and from the delegation of the regulatory port function to an independent authority will be tested over the course of time, the Greece's case which implemented such a venture in the light of the port devolution promoted in its largest ports of Piraeus and Thessaloniki can be considered an ultimate test field for examining such challenges and drawing lessons.

An analysis indicated these actions (i.e., enforcement of economic regulation and delegation of regulatory function to an independent authority) that could become an opportunity for the public sector and the state consequently, to shield and safeguard public interest as well as to regulate efficiently the port network. As such, the enforcement of independent economic regulation within the port sector can become the vehicle that will allow ports to face the challenges posed in the increasingly integrated and concentrated by powerful players, global supply chains.

As international practice has shown apart from Greece, other countries have turned to the establishment of similar agencies with explicit port economic regulatory competencies. In this sense, it seems to be increasingly acknowledged that the establishment of a clear regulatory framework that enables the transparent, fair and non-discriminatory provision of port services, plays a fundamental role in ensuring and sustaining competition rules, while preventing market distortions within the port system.

However, as today's ports apart from the port sub-network (port cluster) simultaneously co-exist in multiple hyper-networks (terminal operators' global network and the door-to-door supply network), economic regulation's reach too, should extend beyond the port's perimeter.

While thus, supply chains extend across the globe and transport actors become more integrated and concentrated in the process of establishing a global transport market, regulations too cannot be confined solely within the port perimeter. As stressed out, it is difficult if not impossible to effectively regulate global players exclusively on a national context or within the context of a port.

To this end, as the battle of competition is shifted from the local to the global level, the need for transnational economic regulations that extend throughout the entire supply chain network emerges.

Following the slow but steady steps, made by EC towards the establishment and enforcement of transnational regulations within the port sector, we have proposed the formulation of transnational and regional regulatory bodies which will be entrusted to stipulate and enforce regulations across the entire supply chains. Following the paradigm of other network industries which are governed by national, regional and transnational regulatory bodies, such an initiative would lead to perceive supply chains not as a sum of distinct nodes, but rather as a coherent and integrated network.

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Expectations and Risks for Greek Ports from the Upcoming Mew EU Regulation for the Trans European Transport Network (TEN-T)

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INTRODUCTION

According to the European Treaty, a Trans-European Network had to be developed in three sectors: Transport, Energy, and Telecommunication. The sector of transportation includes all the transport modes (roads, rail, maritime navigation, inland navigation, and air transport). After a long period of negotiations, Regulation 1315/2013 on Union guidelines for the development of the Trans-European Transport Network (TEN-T) was ratified and inserted into force, with the obligation to be revised in ten years.

THE EU REGULATION 1315/2013

The scope of the Regulation 1315/2013 is described as *"The trans-European transport network comprises transport infrastructure and telematic applications as well as measures promoting the efficient management and use of such infrastructure and permitting the establishment and operation of sustainable and efficient transport services"*.
Two networks, the core and comprehensive were established with 9 corridors. As it concerns the maritime navigation, the ports were nodes of the networks and the Motorways of the seas. 5 Greek ports joined the core network and 20 ports the comprehensive. The criteria for joining the comprehensive network by a port were: a) 0,1% of the mean total European cargo volume at the three last years, b) 0,1% of the mean total passenger's volume at the three last years, c) the location of an island in NUTs 3 region and d) the location in an outermost region or a peripheral area, outside a radius of 200 km from the nearest other port in the comprehensive network. They were no specific criteria for the core network.
The program Motorways of the Seas (MoS) is coming to finance projects via TENT and CEF (Connecting Europe Facility) funding tools.

THE LONG WAY TILL THE NEW REGULATION

Based on evaluation studies results, the European Commission presented a proposal for a Regulation of the European Parliament and of the Council, on Union guidelines for the development of the trans - European transport network, amending Regulation (EU) 2021/1153 on 14.12.2021. The Council of European Union presented on 27.2.2022 an amended new proposal. The European Parliament, via 3 at least commissions, introduced 1872 new amendments. The Council General Approach of 5.12.2022, again, proposed new amendments including the spaceports in the field of air transport.
At these proposals the corridors are extended including also infrastructures in neighboring countries. They were set new deadlines to finalize the projects of common interest of the core, the extended core and the comprehensive network by the end of 2030, 2040 and 2050 respectively.
A new criterion, for the sea ports, will be added, the total cargo volume must exceed 500.000 tonnes and its contribution to the diversification of EU energy supplies. 41 Greek Ports meet now the new criteria, 16 more that in Reg. 1315/2013. One of them (Agioi Theodoroi), who is an industrial port, will join the core network and 15 will join the comprehensive network. Between them the Port of Alexandroupolis is finally concluded. The main benefit for those ports is the possibility of European funding via CEF (Reg.1153/2021).

EXPECTATIONS AND RISKS

During the first period of CEF (2014-2017) only 4% of the financing was going to European ports with a 72% directed to the rail. At the same time the 74% of the total European freight transport is imported by ports. From the total given amount only 0.03% went to Greek Ports. At the next period (2018-today) some Greek Port Authorities participate at pilot projects concerning mostly energy and no infrastructure. Greek ports did not benefit significantly from the MoS programs. Under the new Regulation the MoS will be replaced by the European Maritime Space (EMS). With the existing model of port governance in Greece, it is too difficult for the ports to participate at these projects.
As it concerns the road and rail corridors in Greece the situation does not change significantly compared to the existing Regulation. Even existing roads are not included. The western part of the country is neglected. On the contrary, in the neighboring countries a dense network will be developed, including countries non-EU members. In some cases that will facilitate Greek Network but, in some cases, that will transpose flows from East to the North, ignoring the South.
In Figure 1a and 1b are presented the maps of the proposed TEN-T networks for our area from the Commission and the Council proposals respectively.

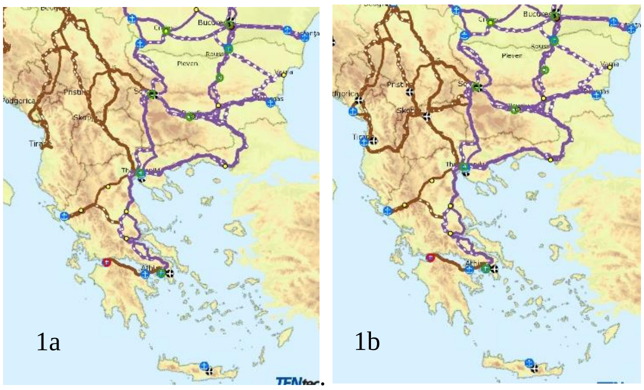

Figure 1. TEN-T networks in South Balkans

More European financial resources, with easier access, should be allocated especially to small port infrastructure and to the connections with the other networks for a resilient, coherent, sustainable, smart and seamless trans - European transport network.

Expansion of a Quay Wall at the Port of Heraklion, Crete: Errors and Omissions that led to the Collapse

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INTRODUCTION

The paper refers to the project "Expansion of a quay wall at the Ports of Heraklion, Crete" and focuses on the mistakes made both, during the initial study period and subsequently after the completion of the project ‘s construction and in the period after scour holes were observed until the final collapse of the quay wall.

THE NEW QUAY WALL

In order to ameliorate the functionality of Heraklion Port, an expansion of the apron area between Pier II and Pier III is proposed. For this reason, an embankment in front of the existing quay wall is designed, with the displacement of the quay wall for 46.0m. The depth in front of the new quay wall is set at -8.0 m, 2.0 m more profound than the old one which was founded at-6.0m, so the new quay wall can be used by ships with a greater draft. The depth of the quay walls from both piers II and III was set at -10,0 m from the M.S.L., i.e., there would be a difference in the bearing height of the vertical to them new quay wall with the old ones by 2.00m. The total length of the new quay wall was 120.0m.

The study was conducted by the Technical Works Department of Heraklion Port Authority, from August to October 1996 based on a preliminary study for Port of Heraklion conducted by consultants. The approval of the study was done by the Department of Transport Works of the Region of Crete.

The construction of the project started on 11-4-1997 and finished on 11-2-1998 and started to be used.

THE PROBLEMS AND THE COLLAPSE

After some time of the new quay wall operation, they were observed foundation settlements (small displacements), especially in the western part of it, where are the Ro-Ro ship's stern mooring area and the stern ramp is supported.

That was accepted as normal by the Head of the Technical Works Department, due to the pressure and friction from the weight of the vehicles being loaded and unloaded. Local interventions were made by the constructor such as the replacement of the backfill material and the placement of concrete.

Due to the continuation of the foundation settlements, two inspections by divers were carried out on 4-12-1999 and 18-12-1999 on the reefed sections of the quay wall, which revealed very large cavitations on the western part of the quay wall, where is the stern mooring area of the ships.

The cavitation was significant with dimensions of 3.50m deep, 1.5-2.0m high, and over 15.00m long. The bearing layer material and the protecting toe plate had been removed from the foundation base of the quay wall. The quay wall, in this area, with this cavitation, ceased to be sited on the ground, it became ready to fall and it functioned temporarily as an arched structure.

On 9-7-2000, the Western part of the quay wall, where the ships were moored, approximately 20m long, collapsed. A second part rotated, while the embankment material leaked out to the sea.

In Fig. 1 a photo of the collapsed quay wall is presented and in Fig. 2 an aerial view of the collapsed area is presented.

Figure 1. The collapsed quay wall.

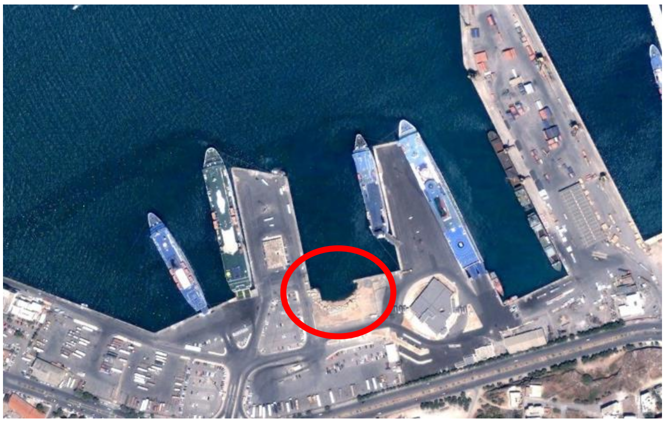

Figure 2. Aerial view of the collapsed area

CONCLUSION

According to expert reports, carried out after the fall of the quay wall, the main cause of the collapse was the extensive scour caused by the action of the ship's propellers, while an important factor that influenced the appearance and extension of the failure and acted as a cause was the foundation of the sea wall, of the embankment and of the relief prism on silt.

Finally, an important role was played by the 8-month delay in taking measures to restore the pre-collapse damage.

The quay wall was reconstructed under a new study and nowadays is fully operational without any problem.

Boomer Sub-Bottom Profiler: also Valid for Distinguishing Habitat Boundaries during Port Geological Surveys? – An example from Armenistis Coastal Zone in Ikaria Island

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INTRODUCTION

The distribution of protected habitats is a key parameter during environmental surveys for port construction studies. Most of the times this scope accompanies bathymetric and marine geological surveys for the detection of geo-hazards (gas in marine sediments, weak layers, instabilities, faults, outcrops etc) that may affect construction activities. Depending on the size of the project and if a multi-beam echo-sounder is not to be used, habitat distribution relies on side scan sonars or, occasionally, habitat echo-sounders. Here, we present the results of an effort to use a Boomer subbottom profiler for the general distribution of habitats and evaluate its efficiency. As a case study, the coastal zone of Armenistis in Ikaria Island (central Aegean Sea) is examined. The initial scope of the project was to examine the subsurface distribution and outcropping of granite, the main bedrock formation found onshore, and other potential geohazards.

METHODOLOGY

The study was carried out in 2022 using a vessel of opportunity for the seismic survey and a supporting 4.5 m inflatable boat. In the absence of valid bathymetric data, initially a Humminbird Helix 10 multi-parametric sonar was used for the acquisition of preliminary bathymetric and seabed morphological information along a grid of dense crossing lines. This is a low-cost sonar able to provide high resolution data for bathymetry (180-240 kHz) and seabed morphology (455 kHz - Chirp technology side scan sonar). SonarWiz 7 was used for post-processing, analysis and mosaicking of the collected sonographs. The subbottom profiler (SBP) was an Applied Acoustics, consisting of a CSP-D 700 Joules energy source, a AA251 Boomer plate mounded on a CAT-200 catamaran and a 12-element hydrophone. A total length of about 20 km of seismic profiles were collected using the SonarWiz 6 acquisition and processing software. A van-veen grab was used for surficial sampling (9 samples) and a drop camera for sonar ground-truthing (24 stations). During the survey the research vessel speed was maintained at about 3 knots. Navigation and positioning was supported by the Humminbird Helix 10 sonar with a position accuracy of ~3 m. In the laboratory, grain size analysis was performed by dry sieving due to the coarse sediment texture. Statistical parameters were calculated using the Gradistat software. All data were imported and processed in QGIS in EGSA87' for mapping purposes.

RESULTS AND DISCUSSION

The bathymetric data revealed relatively steep slope inclinations shallower than 10 m water depth and an irregular relief shallower than ~8 m attributed to bedrock outcropping and deeper than ~10 m ascribed to *p. oceanica* meadows. The study of the subbottom structure, showed 3 main seismic phases (SF) that correspond to specific stratigraphic units. The surficial SF1 concerns the Holocene-Pleistocene deposits consisting of a thin veneer of loose sediments, which overlies older and denser sedimentary deposits. The thickness of this unit varies, locally exceeds 8 m, and decreases sharply towards the west, where the rocky relief emerges. To the north, deeper than 14 m, a distinct prograding depositional sequence is observed. The main characteristic of SF1 is the slightly undulating and locally irregular surficial echo attributed to the relief of *p. oceanica* banks reaching 1.5 m in height. Surficial sampling revealed sandy to gravelly sediments locally with small cobbles, whilst drop-camera verified the presence of *p. oceanica* and sand patches in various depths. The intermediate stratigraphic unit (SF2) is related to sediments of varying composition, but of greater density than SF1, which were probably deposited during the Pliocene-Lower Pleistocene. Finally, the lower stratigraphic unit (SF3) is separated by a clear unconformity from the overlying SF2 and constitutes the hard granitic bedrock which towards the west appears on the surface and presents a highly irregular relief. No major geo-hazards were encountered in the study area.

Careful examination of the Boomer surficial echo acoustic character helped also in the discrimination and manual mapping of the seabed habitat boundaries. *P. oceanica* was found to develop mainly in deeper waters (67000 m^2) in the central to northeastern part of the surveyed zone, the rocky area develops to the west in shallower waters with a spatial extent of 19800 m^2 and the rest part is covered by sand 61200 m^2. However, when the detailed mapping using the Helix side scan sonar records is performed, either automatically in SonarWiz or manually (the latter giving better and more reliable results), the spatial extent of the habitats presents variations, becoming 39300 m^2 for *p. oceanica*, 17200 m^2 for the rocky areas and 87900 m^2 for sand. A 15% over-estimation of the rocky area from Boomer profiles is deemed reasonable, especially considering the worst-case scenario that must be employed in order to reduce uncertainties during port design and construction. On the other hand, a ~70% increase in the *p. oceanica* appearance could arise environmental issues. However, this includes areas of sand patches within the meadow and also towards the shallow limit, the latter easily discernible in satellite images (i.e., Google earth). Apparently, sand opposites *p. oceanica* distribution. Although differences in habitats' spatial extent may exist, the accuracy of their limits using Boomer was found to be very satisfactory. Thus, even if high-resolution sonars for shallow waters could be the essential tools for reliable habitat mapping, it seems that Boomers can also support preliminary habitat distribution.

The Social Acceptance of Autonomous Merchant Ships in Greek Ports

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INTRODUCTION
Fully Autonomous Ships (AS) operate themselves unmanned by remote monitoring. State-of-the-art shipping technology allows remotely controlled operation. The human presence onboard is replaced by sensors and algorithms. The purpose of the current study is to investigate the social acceptance of autonomous merchant ships in Greek ports.

GREEK PORTS
More than 1000 port facilities are located in Greece, and more than 100 with commercial and passenger terminals. The presence of passenger terminals next to the cargo ones will affect their acceptance.

AUTONOMOUS SHIPS BENEFITS
In 1983, the design of ship automation gets started to reduce the staff. In recent years autonomous technology provides remarkable economic and environmental benefits. As a result, AS operation is expected to be increased, due to technological development. Some of the notable advantages of AS compared to the conventional ones are lighter design due to the elimination of necessary crew accommodations, greater capability carrying capacity and operational crew expenses (de Vos et al., 2021). Furthermore, fuel consumption and gas emission are reduced (Allal et al., 2017; 2018). Additionally, AS could prevent collisions and eliminate human errors, especially in the case of general cargo ships, which record the most dangerous and costly sea accidents (de Vos et al., 2021). Collision avoidance systems can introduce themselves well even if a group of other ships presents simultaneously (Hinostroza et al., 2021).

METHODOLOGY
This report presents a systematic literature review and aims to explain who is responsible for handling the AS within the port and if these ships are expected to be socially accepted in the Greek ports. For the purpose of this study, a questionnaire was set up to examine people's opinions and beliefs about AS. After a brief explanation of AS and their accompanied advantages, the questionnaire was distributed to people related to the subject (such as employees of the port or other companies, researchers and relevant students). This research focuses on merchant ships (container, bulk carriers, tanker, general cargo, towing or even auxiliary ships).

RESULTS
The current research focuses on the conception of the technological revolution and ship automatization through a questionnaire. Firstly, it will become clear what type of ships is preferred to be automated between passenger and each type of ship. Responders are asked what is the greatest obstacle to starting the operation of AS and if they will be limited to a research level. It is examined how successful and optimistic is this revolution and the potential profitability of the shipping companies. Also, job diversification is touched upon, as the number of employees is expected to reduce and their skill requirements are going to be modified. In addition, respondents are asked to select the preferred mode of work between working on the ship and remotely navigating it from land. AS can operate by themselves only in deep water. When they come into shallow water, navigation is absorbed by the crew (Burmeister et al., 2014). No special modifications to the infrastructure are required for the AS operation. The research jos is is still in progress and the final results will arise.

CONCLUSION
The aim of this research study is to determine whether professionals are optimistic and positive about the entry of AS. Greek ports could accept due to their benefits, but the intention of operating automated means is affected and depended on social acceptance. Stakeholders would disregard the social, thanks to the overall AS benefits. On the other side, politicians should consider the social cost of AS in their decisions and actions about ports. Nowadays, there is no legal framework for this level of automatization. Future research could expand the need for more specialized personnel with new skills, that will arise. Other research on upgraded technologies has shown crew acceptance after providing incentives, such as better working conditions and financial incentives (OECD, 2021). Moreover, the concern that should be examined in the future is the possible replacement of the staff by technology.

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The Coastal & Ocean Basin and the Research Dike Raversijde: Two New Research Facilities along the Belgian Coastline Supporting Coastal Engineering Research

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INTRODUCTION

Recently, after years of preparation, two new and rather unique research facilities have become operation along the Belgian coastline. The first facility is the wave tank, called the "Coastal & Ocean Basin" or COB, for experimental modelling in the context of research and design of coastal and offshore structures. The second facility is the field measurement site, called "Research Dike Raversijde" or RDR, for measurements of wave overtopping and wave induced loading on storm walls for the case of a sea dike with a very shallow foreshore. Both facilities are located in Ostend, Belgium, and are of general interest as both are accessible for researchers world-wide.

THE COASTAL & OCEAN BASIN COB

The new COB at Ostend Science Park, Belgium is operational since early 2023. The laboratory provides a versatile facility that will make a wide range of testing possible, including the ability to generate waves in combination with currents and wind at a large range of model scales. The COB is funded by the Hercules foundation, the Agency for Innovation by Science and Technology (VLAIO), Ministry of Mobility and Public Works, Ghent University (UGent) and University of Leuven (KU Leuven). The basin is part of the Flanders Maritime Laboratory which also hosts a towing tank. The operational management of the COB is carried out by a team of experts and technicians, under supervision of the consortium UGent, KU Leuven and Flanders Hydraulics.

The COB is 30 m long, 30 m wide and has a variable water depth of up to 1.4 m. A central pit allows experiments e.g., with mooring lines, at a depth in excess of 4 m. The COB has state-of-the-art generating and absorbing wavemakers from Van Halteren and a submerged system for current generation. The wave paddles are 0.43 m wide and produce regular waves with a wave height of 0.5 m for a wave period of 3 s, and random waves with a significant wave height of 0.3 m. Two sides of the wave basin have wavemakers, in an L-layout, offering excellent opportunity to generate highly accurate short-crested wave fields. It is possible to generate wave-current interactions in the same, opposite, and oblique directions and to reach current velocities of 0.4 m/s. Flow velocity fluctuations are expected to be smaller than 10% RMS. For wind generation, a portable device capable of generating speeds up to 15 m/s is foreseen. The basin will be equipped with state-of-the-art instruments for wave, current, wind, kinematic and structural measurements. A 10 t overhead crane will enable easy installation of structures and devices.

The COB allows users to conduct tests for national and international coastal and offshore engineering projects. Figure 1 shows a photo of the tank.

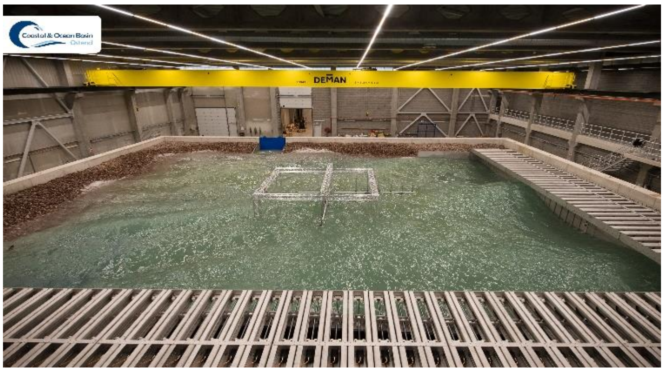

Figure 1. The COB wave tank.

THE RESEARCH DIKE RAVERSIJDE

The field measurement site "Living Lab Raversijde" is located in Ostend, Belgium, where wind, waves, water levels, bathymetry and beach profiles will be measured over 10 years (2022-2031). It consists of (1) offshore measurements using collocated directional wave buoys and ADCP's with a shallow sand bank in between to investigate the generation of infragravity waves; (2) three intertidal poles with collocated current and pressure sensors, and sediment suspension meters to measure the wave transformations and beach profile changes; (3) an artificial dike (RDR) to measure the wave overtopping and impact on storm walls on the dike, and the wind.

The concept of the artificial dike (Figure 2), constructed in front of the real dike, is to bring the dike and instrumentation closer to the sea (at about the spring high tide level on the beach), and was designed with a lower crest level so that every storm season (from October until March) at least 5 storm events can be measured. The artificial dike consists of 4 typical cross-sections, where the overtopping is measured at the dike crest, at the end of a promenade, and the same again, but with a storm wall present where the impact forces are measured.

Figure 2. The artificial dike RDR and intertidal poles at low tide (top left and bottom) and high tide (top right).

Performance of a System of Detached Breakwaters on the South Corinthian Gulf

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INTRODUCTION

The shoreline of the South Corinthian Gulf is experiencing coastal erosion, causing major problems to the inhabitants. The first signs of the problem appeared in the 70s. Later in 1990 a research project was conducted by the Laboratory of Harbour Works (LHW, 1998), NTUA, to investigate the problem. Main result of the project was the classification of the eroded areas according to the risk of land loss. 19 Areas were experiencing coastal erosion. Three areas among them were selected to be protected by coastal structures. Among these three areas, is the area of Kiato, Korinthia, where a system of detached breakwaters was proposed, protecting the whole area up to the fishing shelter of Kiato.

According to that decision, in 2009 a system of two detached breakwaters were constructed at the west side of the Asopos estuary near Kiato, as a pilot project. To investigate the system's performance, a monitoring program took place in July 2017 by taking topographic measurements of the shoreline and granulometric analysis of the sediments.

This paper examines the performance of these breakwaters as well the accuracy of MIKE 21 by DHI, which was used to estimate the shoreline evolution behind the breakwaters. Two main scenarios are simulated. The first scenario uses as a forcing power the equivalent waves in each direction by mean wind data, and the second scenario uses as a forcing power the wind that has been measured in the area for the period from the construction till July 2017. Finally, the results, concerning the evolution of the coastline, of the simulation for the two main scenarios are presented, and compared to the topographic measurement.

WIND DATA

For the needs of the present research, two wind data sets were used. The first one was from meteorological station of Isthmus (2009-2014). In 2015 a meteorological station was installed at Kiato and the second data set was taken from the Kiato station operated by the the National Observatory of Athens. (Lagouvardos et all, 2017) This wind data consists of the speed and the direction of the observed wind. The time step of this time series was 10 minutes.

SHORELINE EVOLUTION

The simulation of the wave field, the current field, the sediment transport as well as the shoreline evolution of the breakwaters area was conducted using two different scenarios. The first scenario was the forcing power using the equivalent deep water waves. That is, for every main direction of wind (north, east, south, west), the characteristics (height, period) of the equivalent deep water, wave was computed from the wind speeds and these waves are used as boundary conditions. The second scenario was the scenario using constantly variable wind as a forcing power. In this scenario the observations of the Isthmus weather station were used for the years from 2009 to 2014 and the observations of the Kiato weather station were used for the years from 2015 to 2016. The initial time series had a time step of ten minutes.

Moreover, three different sub-scenarios were used. Each scenario represented a different diameter of sediment grain. Three different grain diameters were chosen (0.20 mm, 0.25 mm, 0.50 mm) as a sensitivity analysis. The closest to the actual grain diameter size is the size of 0.25mm. Results of the shoreline simulations are presented in Figure 1.

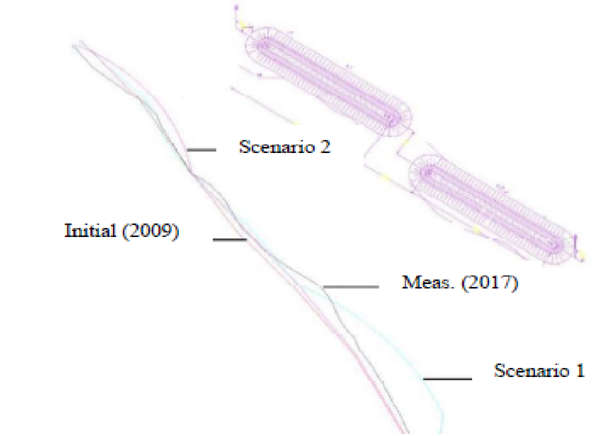

Figure 1. Shoreline evolution

DISCUSSION AND CONCLUSIONS

Following this comparison of the results, it is evident that the approximation of variable winds is the one that calculates more accurately the coastline evolution in this area. This is expected, because the variable wind approximation approaches better the reality of the wind climate of the area. The approximation of equivalent deep waters waves remains merely a statistical approach to the observed waves in the area and may not be suitable for evaluating the coastline evolution. In S.1 the expected areas of accretion and erosion are correct, although with great deviations from the reality.

Also monitoring of the structures performance after their construction is necessary.

ACKNOWLEGEMENTS

We would like to thank DHI and its representative in Greece, Mr. Elias Mousoulis for the concession of the academic license of Mike 21.

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Kinematic Perturbations in Submerged Breakwaters under Waves

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INTRODUCTION AND SCOPE

As environmental awareness gradually increases, submerged breakwaters have become a shore protection alternative to their emerged counterparts, aiming at confining the significant environmental impact of the latter, including low level of water renewal, degradation of the aesthetic value of the landscape, occupation of relatively large seabed areas, etc. Beyond the basic goal of such structures in stabilizing the coast, it has been deduced that especially rubble mound submerged permeable breakwaters (SPBs) may function similarly to natural reefs in attracting marine life. The response of marine organisms to the presence of SPBs has not yet been investigated in-depth. However, hydrodynamic parameters as pore pressures and orbital velocities, inside their permeable body, have been observed to be significant factors in supporting marine life within and around these bars, in terms of, for example, distribution-species biodiversity and abundance. It has been stressed also that, in addition to mean velocities and pressures, extreme values are equally important as key hydraulic factors governing marine habitation levels (e.g. Siddon & Witman 2003).

Even though several studies examining various processes around submerged breakwaters can be found in the literature, the kinematics inside a SPB is a field of relatively less research. This study aims at giving quantitative information on parameters useful to marine scientists for accessing the ecological potential of SPBs on marine life, beyond their technical efficiency.

METHODOLOGY

Within this work, the hydrodynamic field inside SPBs under regular waves is studied through experimental data of (i) orbital velocities' timeseries, in three dimensions, developing inside physical SPB models, focusing on turbulence levels and (ii) the hydrodynamic pressure component evolving inside these SPB models, also including fluctuation levels. To this end laboratory measurements were taken in the: Laboratory of Fluid Mechanics of TUDelft, Laboratory of Harbour Works of NTUA, Hydraulic Engineering Laboratory of UoPatras. The data obtained were analysed and processed. Finally, comparisons between the above data sets were performed, leading to useful results.

DATA ANALYSIS AND RESULTS

The experimental data gathered were filtered and turbulent statistics along with mean values for orbital velocities and hydrodynamic pressures were assorted. The associated time duration at each intensity level was also incorporated. Examples of data processing are given in the following figures. Comparisons were then carried out between the results based on the measurements of the three laboratories.

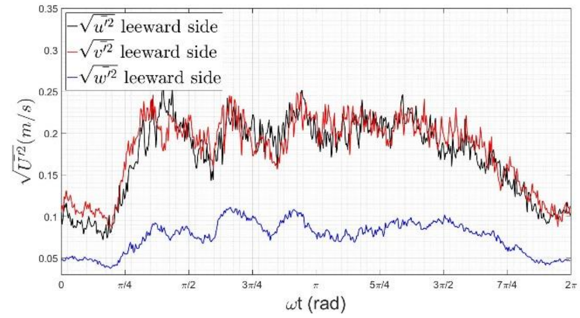

Figure 1. Phase averaged turbulent intensities for orbital velocities at the leeward slope of a SPB, under regular waves.

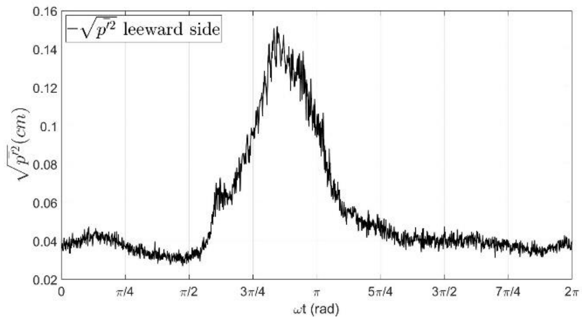

Figure 2. Phase averaged turbulent intensity for pore pressure at the leeward slope of a SPB under the conditions of Fig.1.

CONCLUSIONS

In this study, measurements of physical models of submerged permeable breakwaters were analysed and processed in an endeavour to quantify the perturbations around the mean values of the core hydrodynamic parameters of orbital velocities and hydrodynamic pressures developing inside these structures. Since no similar results of either physical or numerical models have been published to the knowledge of the authors, it was decided to carry experimental tests in three laboratories and compare results between them. The comparisons proved quite satisfactory. It was found that such fluctuations are not negligible in marine biology since they can modify instantaneously the mean values by as much as 25%. Information of this kind would be of great value in relevant studies of marine life habitation in submerged structures. Moreover, the present results would be quite helpful in further research regarding technical aspects, such as wave transmission or structural integrity of those breakwaters.

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Coastal Protection Works of Liopetri's River "Potamos", Cyprus

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INTRODUCTION

Town Planning and Housing Department of the Ministry of Interior of the Republic of Cyprus in cooperation with the Department of Fisheries and Marine Research have undertaken the formation of a fishing port at Liopetri's river 'Potamos' on the SE coast of Cyprus (1st DMPCO, 2019).
During the last decades, illegal building of usually plain sheds and huts on river's banks has been severely increased, widening the river, transform it into a fishing port, while banks' erosion had also been noted.

Photo1. Anarchy erected sheds and huts on the river's banks.

The existed 120 hats and sheds have been placed along the river banks using about 1000 piles of any kind and shape to support the superstructure. The material and the foundation type of each pile, is shown below on figure 2 with a specific mark: wooden columns, steel columns, plastic /asbestos or steel tubes filled with concrete, and even barrels and tires filled with concrete.

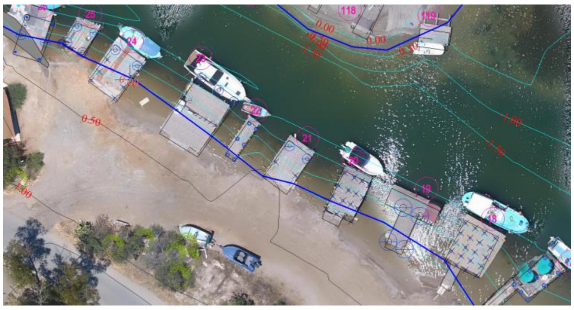

Photo 2. Several platforms supported on different kinds of columns.

CONSTRUCTION WORKFLOW

The initial task was to clear the river banks, removing all superstructures. The existed foundation columns shouldn't just be extracted from the river bed, since they acted to the banks' soil as deep rehabilitation. Even though the river has usually little flow of rain water, there is constant inflow and outflow because of the ebb and tide, causing the fluctuation of the river's level about ± 30 cm. Thus, the numerous columns should be cut off in place with minimum distortion, leaving the soil intact. Only a dozen of asbestos pipes had to be totally removed, due to environmental laws. To accomplish the peculiar task to safely cut every kind of pipe underwater, special hydraulic disc cutters were used successfully.

Photo 3. Clearly cut of wooden and steel column.

As soon as the river was free from old structures, new iron steel columns have been hammered into the designed new positions on the banks of the river. In order to investigate the thickness of the soil upon the rocky background, several steel columns were hammered along the banks of the river, testifying the stiffness of the soil. It became clear that the rocky background was appearing deeper near the rivers' estuary.

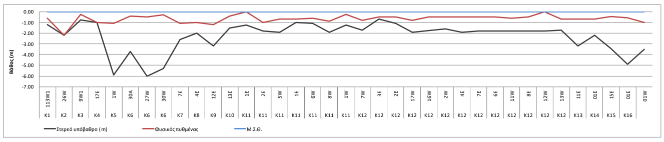

Figure 1. The rocky background level in black line under the red line of the soil, where the blue line stands for the MSL.

One or two gabion baskets filled with stones have been placed between the columns into the banks' soil, being fully submerged in order to prevent corrosion. Natural rock armor is placed to fill gaps and to cover the gabions.

Photo 4. Banks' armor behind support columns.
W o r k s u n d e r c o n s t r u c t i o n !

Coastal Engineering Study for the Rehabilitation of the Beachfront at the Fire-Struck Area of Mati, Eastern Attica

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INTRODUCTION

The present study, as part of the "Urban planning & design implementation", constitutes a marine and coastal engineering investigation, aiming at rehabilitating the coastal front of the fire-struck area of Mati, located at the eastern part of Attica. Beach nourishment along with coastal protection works are proposed to counteract erosion and improve coastal cliffs' stability.

STUDY AREA

The study area of a total coastline length of approx. 3.5 km, is divided in 4 sub-areas, which are examined separately; these are:

i. Kokkino limanaki & Akti Irinis
ii. Argyra Akti
iii. Rocky coastal stretch
iv. Coastline north of N.A.O.M.

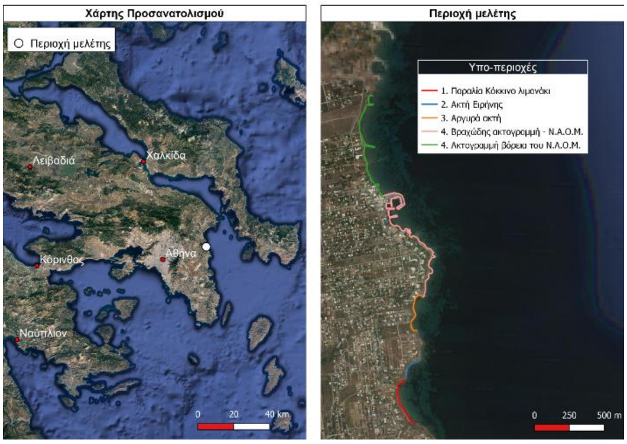

Figure 1. Study area and sub-areas.

COASTAL ENGINEERING STUDY

The following steps outline the methodology of the study procedure applied:

i. Preliminary coastal processes assessment
ii. Assessment of the offshore wave climate.
iii. Calculation of the nearshore wave field using numerical modelling of the Wave Transformation in the nearshore area.
iv. Calculation of the wave induced circulation in the coastal area using a Hydrodynamic Numerical Model.
v. Calculation of the sediment transport rates due to wave induced circulation by using, numerical model.

The numerical models of Mike 21 by DHI were used for the simulations.

Steps [iii] to [v] were carried out for all a number of wave conditions, and for a number of alternative schemes which were considered; based on the results obtained, the optimum solution was selected.

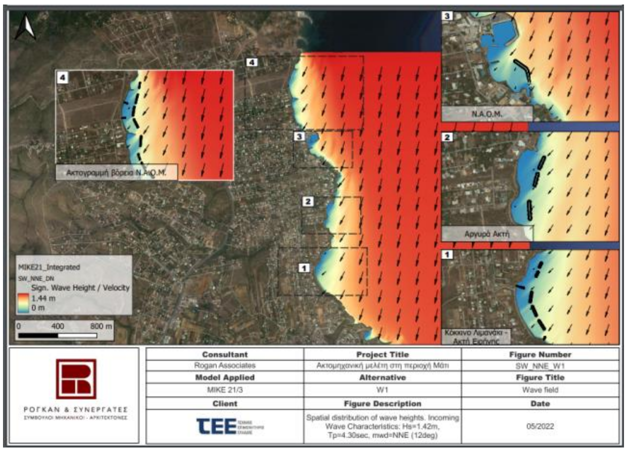

Figure 2. MIKE SW simulation results.

PROPOSED COASTAL PROTECTION WORKS

The main works proposed consist of:

- Beach nourishment at all four (4) existing beaches covering a total length of about 1,65 km.
- Fifteen (15) submerged detached breakwaters, five (5) groins, one (1) emerged breakwater and one (1) sill (low-crested rubble mound) for the protection of the rehabilitated beaches
- A coastal pedestrian walkway (promenade) of approx. 310 m long.

Figure 3. Layout of proposed coastal protection works.

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A New Time-Dependent Irregular Wave Propagation Model

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INTRODUCTION

In this paper a time-dependent numerical model for the simulation of irregular multi-directional wave propagation and transformation in coastal areas, around and inside ports and harbors is presented. The model is capable of simulating the transformation of complex wave fields including shoaling, refraction, diffraction, total and partial reflection from structures, energy dissipation due to wave breaking and bottom friction in a combined way.

THE 2DH MODEL

The model equations are expressed in terms of the surface elevation and the depth-integrated velocities. A wave spectrum is decomposed in N waves. The model consists of the following pair of equations:

$$\frac{\partial \eta_i}{\partial t} + \frac{c_i}{c_{ig}} \nabla \frac{c_{ig}}{c_i} \mathbf{Q}_i = 0 \quad (1)$$

$$\frac{\partial \mathbf{U}_i}{\partial t} + \frac{c_i^2}{d} \nabla \eta_i = \nu_h \nabla^2 \mathbf{U}_i \quad (2)$$

where η_i is the surface elevation, $\mathbf{U}_i$ is the mean velocity vector $\mathbf{U}_i = (U_i, V_i)$, d is the depth, $\mathbf{Q}_i = \mathbf{U}_y \cdot d$, c_i the celerity, c_{ig} the group velocity, and ν_h is a horizontal eddy viscosity coefficient. The subscript i denotes the i-th wave component. The last term of equation (2) is introduced to include breaking effects (according to Karambas and Samaras, 2017).
Equations (1) and (2) are solved N times separately for each wave component i. Each time step the surface elevation and the horizontal velocities are calculated from the sum of each wave component:

$$\eta = \sum_{i=1}^{N} \eta_i, \quad U = \sum_{i=1}^{N} U_i, \quad V = \sum_{i=1}^{N} V_i \quad (3)$$

MODEL APPLICATIONS

Firstly, the model is applied to simulate irregular wave propagation over an elliptical shoal, reproducing the Vincent and Briggs (1989) experiments. The wave transformation is mainly due to bathymetric effects (refraction and bottom diffraction). Figure 1 shows a comparison of the model results for unidirectional spectral waves against the experimental data along the transect No. 4, which lies behind the shoal (test U3, incident significant $H_i = 0.0254$ m, peak period $T_p = 1.3$ s). The comparisons show a good agreement between the model results and the experimental data (Figure 1).
The second set of numerical experiments concern irregular wave diffraction through breakwater gaps (Li et al., 2000). The incident significant wave height for the case of unidirectional irregular waves is $H_s = 0.05$ m, and the peak period is $T_p = 1.2$ s. Figure 2 gives the cross-sectional distribution of the diffraction coefficients at a distance $y = 3L$ from the breakwater for the case of gap width $B = 3.92$ m, $B/L = 2$, (where the wavelength L corresponds to T_p for irregular waves). Comparisons of model results against experimental data are proven to be satisfactory.

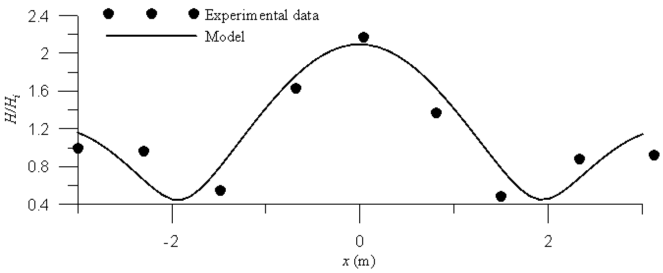

Figure 1. Comparisons of model results against experimental data of Vincent and Briggs (1989), in terms of normalized wave height H/H_i, for spectral unidirectional waves.

The model is also applied to the Port of Thessaloniki (Figure 3). A comparison with a simplified mild-slope equation model shows unimportant differences in wave height distribution.

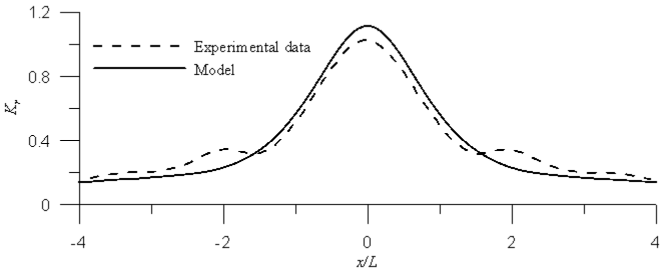

Figure 2. Wave diffraction behind an infinite breakwater (Li et al., 2000). Comparison of diffraction coefficient K_D at a distance $Y = 3L$ from the breakwater.

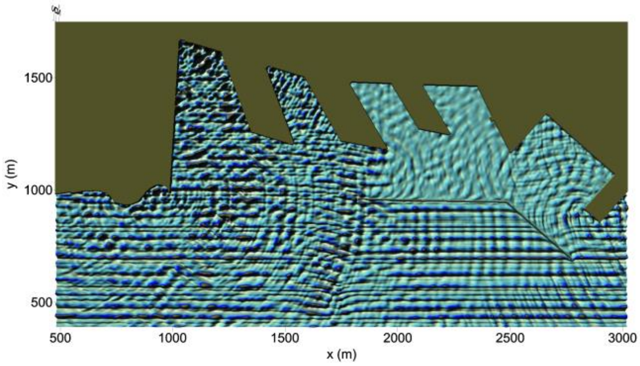

Figure 3. Snapshot of free-surface elevation for incident irregular waves from the southern sector in Thessaloniki port.

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LES of Wave Propagation on a Beach with Different Vegetation Characteristics

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INTRODUCTION

Natural coastal vegetation (CV) fields can attenuate the impact of storms on beaches and coastal structures by dissipating energy of waves and currents. The majority of experimental (field and/or laboratory) and numerical studies in the literature consider the propagation of non-breaking waves past a CV field on a horizontal bed with emphasis on the wave attenuation. The main objective of this work was to study the effect on wave propagation of a CV field on a beach with constant slope. Over a horizontal bed, wave attenuation is the sole hydrodynamic process, whereas over a sloped beach profile, wave attenuation is in competition with wave shoaling affecting wave breaking. In this study, an in-house 3D, LES-type, flow model was used where the effect of a vegetation field was taken into account by implementing a porous medium approach. Different vegetation densities and heights were studied to clarify their effect on wave reduction.

METHODOLOGY

In the present work, the combined water and air flow is modelled as one-fluid flow governed by the 3D incompressible Navier-Stokes equations, whose formulation is based on an LES approach, and it is appropriate to model flow in porous media with constant porosity (Liu et al. 1999). The location of the water-air interface is tracked using the level-set method. The 3D implementation of the Immersed Boundary (IB) method in Dimas and Chalmoukis (2020) is used here to impose the flow boundary conditions on the seabed. The porous medium approach is used to model the flow resistance in the CV field. To this purpose, an equivalent porosity, n_{eq}, is utilized, obviously different to the beach porosity, which depends on the combined effect of CV plant density and its cross-sectional dimensions.

The porous medium model replicates accurately a case in Augustin et al. (2009), where the free-surface elevation was provided for monochromatic waves propagated past a horizontal submerged vegetation field (**Figure 1**).

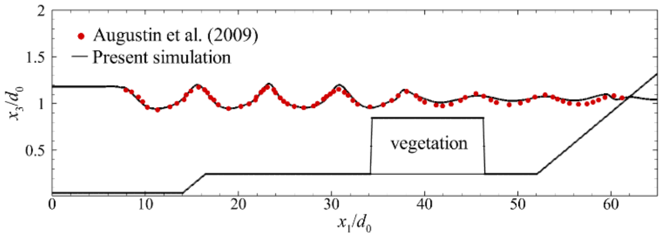

Figure 1. Numerical result of the free surface elevation along with the corresponding experimental measurements in Augustin et al. (2009) where H = 12 cm and T = 1.5 s. The vegetation field comprises cylindrical stems of h_v = 0.3 m and D = 12 mm with a density 97 stems/m^2 (n_{eq} = 0.99).

RESULTS AND DISCUSSIONS

Numerical simulations of wave propagation and breaking over a beach of constant slope tanβ = 1/15 have been performed, with and without the presence of a CV field. The CV parameters were selected to mimic observations of real meadows where CV density, as well as shape and dimensions of CV stems, vary greatly. To analyze the effect of the vegetation characteristics, different n_{eq} values and vegetation heights were considered and simulated. For all cases, the Reynolds number based on the water depth at the position of the wavemaker (d_0 = 0.60 m) is equal to $Re_d = 1.3\times10^6$. The characteristics of the incident waves correspond to laboratory scale dimensional values of H = 0.18 m and T = 1.68 s.

In **Figure 2**, the streamwise velocity field is presented for two cases (n_{eq} = 0.98 and 0.82). The porous medium model appropriately reduces velocity magnitudes inside the vegetation zone. It is interesting to note that the velocity reduction in Case 2 (n_{eq} = 0.98) is almost negligible, since the porosity value is very close to unity, whereas as the CV field becomes denser (n_{eq} = 0.82), the velocity reduction increases. This highlights the importance of the correct estimation/calibration of the vegetation parameters to correctly model the CV effect on waves and flow.

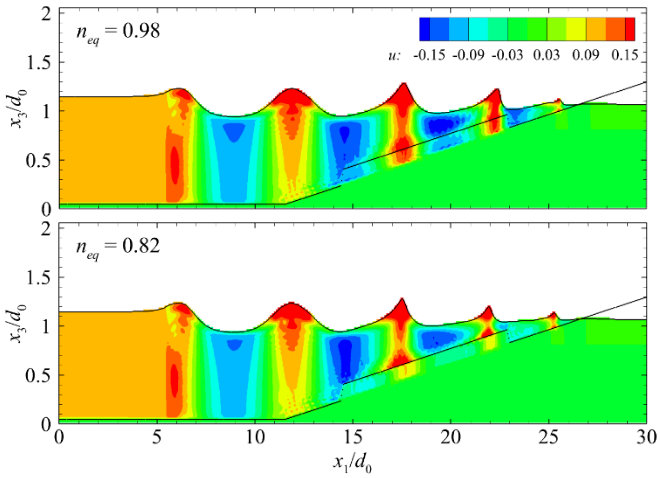

Figure 2. Instantaneous 2DV snapshots of streamwise velocity induced by waves propagating over CV fields with different n_{eq}.

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Coastal Engineering Applications in Greece from a Consultant's Point of View

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INTRODUCTION

Modelling the beach morphodynamic evolution at a particular coastal site requires a deep insight into the existing dominant physical processes. Since these processes take place in different spatial and temporal scales, a set of models has to be used, to capture this complex morphodynamic evolution. Thus, the application of well-known software packages used in consultancy is demonstrated in this work to underline our modelling approach of real case studies. Specifically, coasts in Greece were modelled such as Menidi and Buka beach in Amvrakikos Gulf, and Amarynthos beach in Euboea. Consequently, the full results will be presented.

METHODOLOGY

The standards which determine the deliverables regarding a coastal engineering project require detailed predictions of coastal morphodynamic evolution in short, medium, and long-term time scale.

Particularly, the assessment of shoreline evolution, 2D seabed predictions, and cross-shore profile morphodynamic simulations were performed. To this end, a combination of different software packages developed by Deltares, a world leader in the field of Coastal Engineering were applied, such as UNIBEST, Delft-3D and Xbeach.

SIMULATION RESULTS

Indicatively, some results are presented in this abstract regarding Menidi beach in Amvrakikos Gulf:

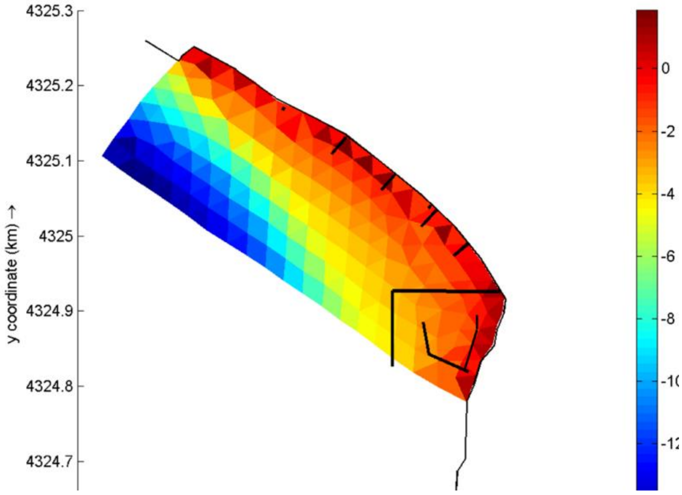

Figure 1. The computed 2D bathymetric 1-year prediction via the software pack Delft-3D.

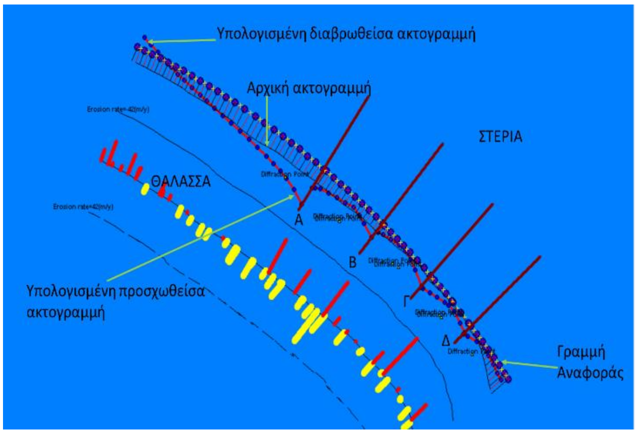

Figure 2. The computed 1-year shoreline prediction via the software pack UNIBEST.

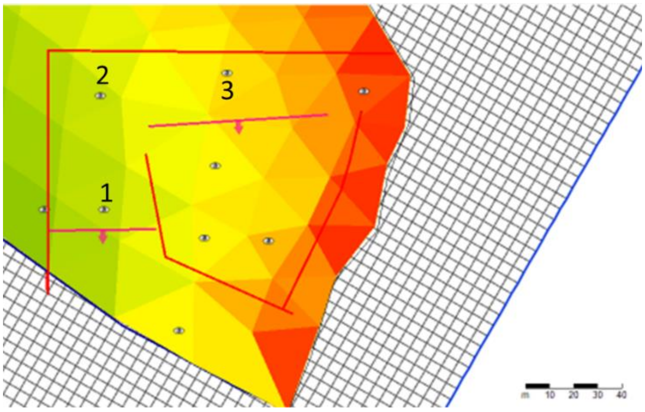

Figure 3. Predicting the expected wave characteristics inside the proposed port of Menidi at the positions: 1; 2 and 3.

CONCLUSIONS

The combined usage of different morphodynamic models focusing on different time scales but also on different coastal process can provide the necessary feedback to analyze accurately a coastal system, provided that we have correctly considered in advance the main causes of morphodynamic evolution (Valsamidis et al. 2021).

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Offshore Infrastructures in Greece: A New Era and a Big Challenge for Marine Geotechnical Surveying

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INTRODUCTION

The Interconnected Electricity Grid (IEG) of Greece supports the highly energy-demanding Ionian and Aegean Sea Islands that are close to the mainland with submarine power cables. For non-interconnected islands, the Independent Power Transmission Operator (IPTO) considers that their connection to the IEG is a necessity. This will lead to a more sustainable electrical grid for the country as well as in the abatement of greenhouse gas emissions. Furthermore, it introduces the possibility of renewable energy sources penetration for the Aegean Islands, with offshore wind farms being a particularly promising source of energy. Moreover, Greece's anticipated role as an energy hub for southeast Europe is corroborated by a series of projects that are primarily related to offshore natural gas facilities (LNG FSRUs and pipelines). Marine geophysical surveys are routinely conducted to support installations for these infrastructures. For geotechnical surveys, sampling is commonly employed with gravity-coring, usually with poor results. More sophisticated geotechnical surveying, involving boreholes or vibro-coring (VC) sampling and in situ measurements (piezocone cone penetration test - CPTU), is rare. In the last decade, few marine geotechnical surveys have applied such methodologies for the safe installation and burial assessment studies of power cables and pipelines. In light of the increasing number of planned power interconnections and other construction offshore activities, including the demand for precise information on the geotechnical behavior of hosting sediments, this paper (i) proposes the idea of developing a marine geotechnical data base for Greece, (ii) addresses the need for valid results from CPT software algorithms for the Greek marine geological conditions / environments and (iii) presents an example of a dataset between Evia and Skiathos with questionable shear strength CPTU profiles and VC laboratory measurements.

CHALLENGES IN MARINE GEOTECHNICAL SURVEYING

The description of prevailing sedimentary processes and marine geohazards for sites with offshore infrastructure is dependent on geophysical surveys. When considering structure installation, however, it is imperative that sampling and geotechnical testing is conducted on surficial and deeper sedimentary layers. This is done for engineering/designing purposes as well as for the validation of geophysical profiles. For example, burial assessment studies rely on the definition of questionable geological strata and their physical and mechanical properties. Even after geological strata have been characterized according to their geotechnical properties, uncertainty can still exist. The uncertainty is usually produced from problems associated with the physical conditions of the study area (sea state, seabed slopes and topography) and the laboratory handling of specimens. An important rule that must be respected is that no sampling method in the sea can provide massive undisturbed samples. Even though this is not a new problem, it can produce unreliable estimations of important parameters such as undrained shear strength. Experience shows that operators do not always conduct sampling properly, thus, disturbance can occur from the initial stage of operations. Disturbances also occur during transportation and laboratory treatment of specimens. For these reasons, important parameters such as bulk density, undrained shear strength, consolidation properties etc., are often questionable. Especially for undrained shear strength, differences in laboratory testing (vane test, triaxial tests etc.) can produce discrepancies in its estimation. In-situ testing, although expensive, provides more reliable results of the subsurface conditions. Nonetheless, issues in the interpretation of CPTU measurements can also arise. Specifically, software packages are employed in order to process and correct CPTU readings. Apart from the basic CPTU parameters (cone resistance, sleeve friction, pore pressure), profiles of soil parameters can also be extracted such as undrained shear strength and relative density. These profiles are based on empirical relationships between CPTU parameters and lab measurement of soil indexes, stemming from various databases. Such readings are deemed unreliable and require validation with lab tests. VC can assist in providing longer cores for testing, which also enable the correlation and ground-truthing of seismic data. Boreholes, on the other hand, are logistically demanding and expensive and they are carried out only for big foundation projects, usually in coastal waters. The study of shear strength from a CPTU-VC dataset between Evia and Skiathos demonstrated considerable differences between the lab and CPT measurements. Shear strength from the lab (measured by vane test) were found to be closer to the remolded undrained shear strength from CPT, while shear strength from CPT was higher, emphasizing uncertainties between measurements.

OPPORTUNITIES IN MARINE GEOTECHNICS

Big offshore projects are initially based on well documented desktop and front-end engineering design studies, which rely on the availability of public or private datasets. Open access of geotechnical data is currently not possible in Greece due to being classified by the companies that supervise the offshore infrastructures. This hinders researchers from examining the geotechnical behavior of sediments for the Greek seafloor. Examples of open-access data use can be found in the Netherlands, where they have established a free-access policy, which has allowed the development of models as well as site-specific correlations. The big number of running or foreseen offshore projects in Greece creates a unique opportunity for building a structured database controlled/handled by competent agencies. Moreover, it has become obvious that there is a need to validate CPTU soil parameters as well as Soil Behavior Types (SBT), since they have been developed from different geological environments. A Greek geotechnical library can facilitate such endeavor and provide readings that would be representative of the Greek seafloor.

Satellite Derived Bathymetry (SDB) with no Use of Field Data

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INTRODUCTION

According to the official European Union (EU) demographic statistics, about 70% of the world's population lives and work, up to 100 km off the coast. Furthermore, almost 50% of the EU population lives less than 50 km from the sea. Nearshore bathymetry is required for a wide range of scientific and engineering applications since coastal waters are areas very dynamically changed. It is still a challenge the fact that exploiting the techniques of remote sensing, depths can be modeled over large and remoted coastal areas, consisted of dangerous hazards, submerged objects and steep morphology of seabed, included a wide rage of benthic diversity, a process which introduces new perspectives to the coastal management issues.

SCOPE OF THE ARTICLE

Remote sensing imagery provides a mean to acquire marine environmental observations in order to understand the dynamic nature of coastal areas and its change in various temporal and spatial scales. In nowadays the satellite imagery can provide users with high resolution and temporal environmental information. This issue is very critical, when scientists need to monitor the species bio-diversity and coastal productivity or coastline change at small scales (spatially and temporary) as well as to take measures for enhance the coastal areas management or protecting their vulnerable marine ecosystems.

In satellite extracted bathymetry techniques, most of the times, there is a requirement for performing appropriate calibration and validation procedures. A crucial factor of the accuracy of the modeled depths is the quality of the field data used for the Satellite Derived Bathymetry (SDB) model training. However, the ground truth data acquisition, is a time consuming and expensive issue. Recent research proves that an alternative solution for SDB models fusion can be data collected through the Ice, Cloud and Land Elevation Satellite-2 (ICESat-2). NASA's ICESat2 launched in September 2018 carrying the Advanced Topographic Laser Altimeter System (ATLAS).

The main aim of this article is to model bathymetry, using exclusively satellite data, by testing the ATLAS altimetry data in relation with a Hybrid Bio-optical Transformation and the use of a Very High Resolution (VHR) imagery, exploiting open-source data, open-source software, taking into account the requirements for minimum manpower.

METHODOLOGY

The geographic area selected for this research is the Laganas bay that covers a coastal area at the southern part of Zakynthos Isl., in Ionian Sea (Greece). The use of high-resolution imagery investigated, in this study, acquired from PLEIADES satellite constellation. Also, ICESat-2 altimetry data downloaded free of charge that utilized as the ground truth data in the framework of the present experiments for validation purposes. Satellite bathymetry extracted using the Hybrid Bio-optical Transformation (HBT) according to the model described by Mavraeidopoulos *et al.* (2019).

Recent experiments (Parrish, *et al.*, 2019), shown that after relevant data processing and analysis, the ICESat-2 data can be exploited to calibrate high-resolution imagery, in order to provide coastal bathymetry. Careful treatment required during pre-processing data phases for selecting only the photons of ICESat-2 that derived exclusively from the seabed of the image area.

CONCLUSIONS

Results show that it is possible to model bathymetry using exclusively spaceborne data, with no need to use expensive ground truth bathymetric measurements in coastal areas, with depths between 0-30 m approximately, with an average RMSE of 2.70 m (Figure 1).

Further research is required to improve the accuracy of the method described in this article with the scope to reduce the average RMSE. Checks also needed to certain that the vertical datum transformation is correct during the ellipsoidal heights conversion to Orthometric ones. Generally, the error budget could be minimized if the refraction effects minimized.

Bathymetry data derived from exclusively spaceborne data can be used in a diverse range of objectives related to marine management, by monitoring coastal environmental parameters and phenomena and providing the interested stakeholders and planners with cheap but very significant ecosystem information.

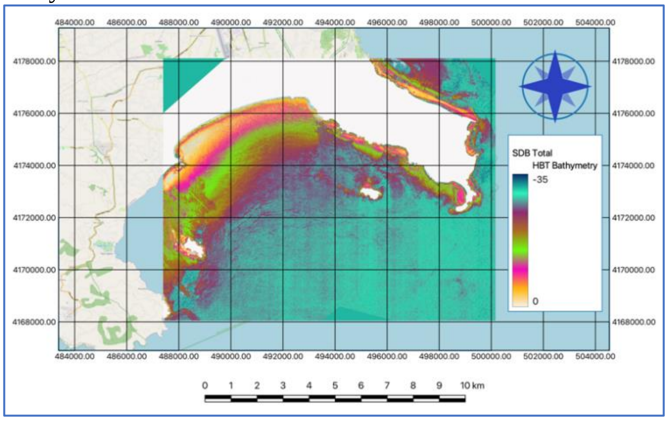

Figure 1. Satellite Derived Bathymetry in Laganas bay coastal area.

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Seabed Conditions in the Embayment of Agia Efimia (Kefalonia) Two Years after the Medicane Ianos

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INTRODUCTION

The Mediterranean tropical-like cyclone (Medicane) IANOS stroke the southern Ionian Islands in September 2020, causing devastation in local infrastructures. In the eastern part of Kefalonia, Agia Efimia experienced damages due to widespread flooding, mud and debris flows but also due to the strong winds and waves. Mud flows drained at the port of Agia Efimia altering the morphology and the local environment. Natural materials (i.e., branches of various sizes), but also several objects of man-made origin deposited in the port and the wider embayment. A large volume of these items was removed by volunteers and crews of the Municipality of Sami immediately after the bad weather. During summer 2022, dredging works were carried out in the port aiming to clean it from transported natural materials that had altered the relief and caused shallowing, especially in its northern part, near the pier where tourist boats are moored. In addition, the Municipality prepared plans to upgrade the existing port facilities, for improving the safety level of berthed vessels. In September 2022 a coastal survey took place to evaluate the seabed conditions (i) in relation to the existence of soft/loose sediments that may be related to the materials deposited during the IANOS Medicane, and (ii) comparatively between the port and the wider embayment.

METHODOLOGY

The survey was carried out using a 4.5 m inflatable boat along a grid of dense crossing lines and a 7-m boat for coring. Navigation, positioning, bathymetry and seabed morphology was supported by a Humminbird Helix 10 multi-parametric sonar. The sonar although designed for general use in shallow waters, it can provide high resolution information. It uses 180-240 kHz for bathymetry and 455 kHz (Chirp technology) for morphological (side scan sonar) mapping. Position accuracy was 3 m and depth accuracy 0.5% on each measurement. SonarWiz was used for post-processing, analysis and mosaicking of the collected sonographs. 21 drop camera stations were selected for ground-truthing. A small gravity corer (1.0 m long) and a van-veen grab managed to collect 12 small sediment cores (9 attempts failed) and 17 surficial samples, respectively. In the laboratory, grain size analysis was performed by the pipette method for the fine sediment and dry sieving for the coarser grains. Statistical parameters were calculated using the Gradistat software. All data were imported and processed in QGIS in EGSA87'.

RESULTS AND DISCUSSION

The bathymetric survey showed an even seabed at the wider embayment with steeper slopes occurring at the southern part of the study area, in continuation to the onshore rocky outcrops. A zone of irregular microrelief was observed to the north, at the outer edge of the port, coinciding with the dredged area. The side scan sonar survey revealed five backscatter (reflectivity) patterns; the first is related to the smooth relief and is indicative of fine-grained sediments, the second to *p. oceanica* developing to the southern part of the embayment, the third to rocky exposures and/or densely distributed boulders, the fourth to the presence of scattered coarser material (cobbles to boulders) and the fifth to anomalous micro-relief related to dredging operations. Various targets were also observed in the sonar images, and they were found to be (after inspection with the drop camera) of human (anchor scars, suspended chains, big public wheelie waste bin, tires, a small almost buried boat, etc) but also of natural origin (i.e., tree or bush branches, boulders), most of them carried away by the intense stream runoffs induced by IANOS.

The small sediment cores verified the presence of two distinct layers. The surficial layer (A) is 10-46 cm thick, fine-grained (mud to sandy mud) and consists of a surficial lamina (1-5 mm) of dark brown mud overlying dark grey or dark brown to grey or almost black muddy sediments with roots, small branches, leaves, pine needles and pieces of wood. The terrestrial origin is undisputable, however the dark to black color of the sediments is also indicative of high organic content probably related to human activities. Benthic activity appears to be absent except from few very small biogenic fragments occasionally found in the samples. The subsurface layer (B) is usually separated by a distinct unconformity from layer A, it consists of sandy mud to gravely muddy sands, locally with small gravels, it is brown to grey-brown in color with biogenic fragments of various sizes and occasionally with remnants of seaweeds. The existence, locally, of small pieces of leaves/plants of terrestrial origin is possibly related to older stream runoff deposits. It seems that layer B represents the natural sedimentary bed of the embayment. The surficial (grab) sediments correspond to layer A, with slightly coarser material observed to the west but also to the central part of the port, probably related to mixing during the dredging works.

It is evident that during the intervening period between IANOS Medicane and the present sampling (about 2 years), mixing of the sediments took place (a) with materials of anthropogenic origin (mainly sewage) flowing into the bay, (b) due to hydrodynamics (waves and coastal currents) and (c) to a lesser extent, due to seasonal disturbance from the mooring of vessels. It becomes obvious that, at present, the main concern must be management's plans to be adopted in order to reduce human intervention and improve/restore the environmental quality of the wider area.

The Importance of Hydrography in Local Seismic Activity Monitoring: a Case Study in Katakolo Port, Kyparissiakos Gulf, Western Peloponnese, Greece

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INTRODUCTION

Modern hydrography plays a primary role in the proper design and construction of sustainable and safe ports, and in both seabed and coastal monitoring. The reconnaissance of the survey area characteristics will contribute to the better understanding of the local seabed morphology, whilst processing of the survey data may uncover minor anomalies in the present underwater seismic profile of the area, that otherwise might have gone undetected.

In our study, a 3D hydrographic survey took place in July 2022, in the port of Katakolo, Kyparissiakos Gulf, Western Peloponnese, Greece (Figure 1). It was a challenging project, considering the gas seepages that are detected there, leading to the formation of circular depressions, that are called pockmarks (Etiope et al., 2006). These hydrographic observations require immediate attention and comparison with past seismic profiles recorded in the area, as well as assessing the seabed current status. Such seepage may endanger the structural stability of both seafloor and marine constructions, as well as human life and ship safety, since Katakolo is one of the most visited ports in Greece, attracting annually thousands of cruise ships and yatchs.

METHODOLOGY AND RESULTS

For the port bathymetry, a multibeam echosounder was used, along with a GNSS sensor equipped with a DGPS antenna, for positioning computations, as well as for tidal-level estimation. Therefore, Hydrographic surveys must be conducted based on standards, that depend on the intended use. The Katakolo survey was conducted according to the 6th edition of IHO (International Hydrographic Organisation) standards, requiring a 200% seabed coverage, meaning the overlapping among neighbor scannings. For this reason, the survey used the boustrophedon cellular decomposition method (Choset, 2000). Furthermore, in order to avoid false depths, the water salinity and temperature at Katakolo port were measured by a thermosalinometer device, and the sound velocity profile was calculated by applying the Mackenzie equation:

$$c(D,S,T) = 1448{,}96 + 4{,}591 * T - 5{,}304 * 10^{-2} * T^2 + 2{,}374 * 10^{-4} * T^3 + 1{,}34 * (S - 35) + 1{,}63 * 10^{-2} * D + 1{,}675 * 10^{-7} * D^2 - 1.025 * 10^{-2} * T * (S - 35) - 7{,}139 * 10^{-13} * T * D^3$$

The analysis and processing of the data was carried out with the use of a new and modern hydrographic software. More particularly, the surveying data had to be cleaned from the noise created by factors, such as fish, anchors, sediments or fluids, using either automated filters or manualy. However, before applying filters, the evaluation and interpretation of the data, as well as the preservation of selective noise, are of great importance, especially when surveying a port with the peculiarities of the study area, meaning the presence of pockmarks. Although multibeam field scans provided an adequately covered seafloor, there were still gaps that needed to be filled using interpolation methods. The final bathymetric map is shown in Figure 1a and pockmark detection in 1b.

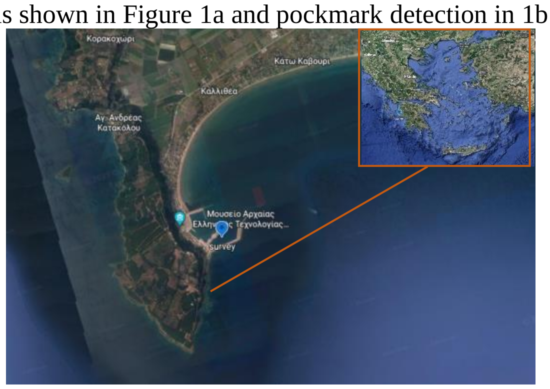

Figure 1. Chartographic illustration of Katakolo.

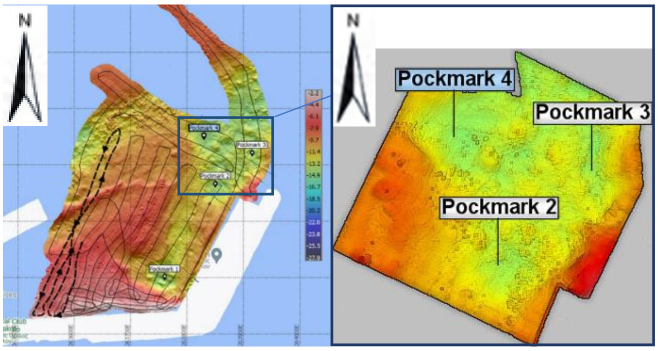

Figure 2. (a) The Katakolo port bathymetric processed data, (b) The detection of pockmarks in the study area.

CONCLUSION

The construction of safe ports and the maintenance of functioning depths are both within the principles of IMO (International Maritime Organisation), which sets the technical provisions in the SOLAS (Safety Of Life At Sea) Convention. Modern Hydrography prvides the means for complying with these demands and standards, whilst enabling a better understanding of seafloor mechanisms, as well as improving the positioning of marine constructions and the operationality of already existing ports. We point out the need for regular (e.g. annual) hydrographic surveys of the Katakolo port to accurately estimate the generation rate of pockmarks, allowing local authorities to prevent possible port incidents.

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