

Ph.D. Program in Civil, Chemical and Environmental Engineering  
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**Wave hindcast development and applications: from wave energy assessment to wave systems detection in the Pacific Coasts of Central America and Mediterranean Sea**

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WAVE HINDCAST DEVELOPMENT AND APPLICATIONS: FROM  
WAVE ENERGY ASSESSMENT TO WAVE SYSTEMS DETECTION  
IN THE PACIFIC COASTS OF CENTRAL AMERICA AND  
MEDITERRANEAN SEA

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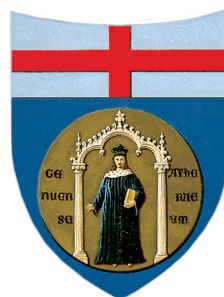
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*To my parents, Matilde and Victor*



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## DECLARATION

I hereby declare that the work presented here has been developed by me, or in collaboration with other colleagues, in an authentic manner and has not been submitted to any other institution for the purpose of obtaining a degree or academic qualification.

Chapter 2 of this dissertation has been published in the journal *Sustainability*, titled as: *Feasibility of Wave Energy Harvesting in the Ligurian Sea, Italy*, under the authorship of Manuel Corrales-Gonzalez, George Lavidas, Andrea Lira-Loarca and Giovanni Besio.

The work presented in Chapter 3 is under review by the journal *Frontiers on Marine Science*, a paper entitled *Wave energy assessment and wave converters applicability at the Pacific coast of Central America*; co-authored by Manuel Corrales-Gonzalez, George Lavidas and Giovanni Besio.

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Manuel Corrales-Gonzalez  
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# SUMMARY

Ocean waves carry various implications for socio-economic activities in the marine environment. The study of ocean waves at a given site is crucial e.g., to ensure safety to infrastructures placed both off-shore and in coastal areas, to characterize littoral transport and coastal morpho-dynamics, to infer useful information for marine eco-systems management, among others. Therefore, the proper characterization of the wave climate is of paramount importance.

In this framework, wave main characteristics such as significant wave height, mean and peak periods and directions, can be forecasted and/or reconstructed over past time slices (i.e., the so called hindcast or reanalysis) through proper numerical models capable to describe the main physical processes involved in the growth and development of random sea states. Several wave hindcast databases have been developed worldwide; however, to date, high-resolution databases are still not available in the Central American Pacific region. Nonetheless, in-situ wave records have been logged at several coastal locations in the area, allowing a proper calibration and validation of wave modelling, opening the door activities of the present PhD research.

The Central American Pacific region analyzed in this study includes the national sea waters belonging to the following countries: Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia and Ecuador. This study yields a reliable benchmark for the regional wave climate that will serve as a reference for activities such as coastal protection, navigation, fishing, offshore operations and tourism, which are relevant to this region. In particular, maritime trade by vessels is of pivotal importance along the studied region owing to the presence of the Interoceanic Panama Canal.

Waves represent an energetic resource that can be adopted as a new sustainable source of energy to supply into the renewable electricity mix. The net wave energy production is directly related to the wave characteristics and the employed extraction devices. There exist wave energy harvesting devices that work on different principles of mechanical energy transformation and their adaptation to the regional wave conditions is crucial for an efficient exploitation of the resource. Whilst wave energy is currently in the early development stages, the evaluation of the efficiency of converters and their adoption in specific regions represents an important milestone for the implementation of wave energy exploitation projects.

The main scope of the present PhD thesis is to develop and analyze a sound and rich wave hindcast in order to provide useful indicators for marine energy exploitation projects and for the characterization of the wave climate. First, an optimized wave hindcast is implemented, spanning the 1980-2021 period, by the use of the WavewatchIII numerical model. Wave characteristics are estimated over an unstructured computational grid with a resolution of 1 km between nodes along the Pacific coastline of Central America. The zeroth-order wave height ( $H_{m0}$ ) produced by the wave model is calibrated on the basis of satellite data. Calibrated wave data is then validated with wave records measured at different locations distributed in the coastal

zone.

Next, a wave energy assessment and the analysis of the wave power potential is developed considering nine energy converters through the Central American Pacific region; after validating the workflow for wave energy assessment, the analysis is replicated in the Ligurian Sea by accounting for eight different devices. Both marine environments present wave characteristics that differ from each other, however, the wave energy potential in the Ligurian Sea and in the Pacific coast of Central America are quantitatively similar, both are classified as low energy seas. The best wave energy converters were found for both regions going through an analysis of the best performing scale in order to improve the called "Capacity Factor" of the different devices.

Finally, as complementary research, a methodology for the detection of directional wave systems is presented: the method relies on image segmentation algorithms and is applied to several hindcast nodes in the Mediterranean Sea. As a result, a new methodology for the automated detection of wave systems was developed, which also allows to estimate the occurrence and simultaneously of the existing wave systems in the Mediterranean Sea, with a specific attention related to those ones crossing seas, important mainly for safe navigation, coastal and offshore engineering projects, and marine energy exploitation.



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