PhD Program in Maritime Science and Technology

Curriculum in Engineering for Marine and Coastal Environments

June 2024 Call, XL cycle - Starting date: 1st of November 2024

The research projects submitted for the admission to the PhD program must be prepared in accordance with one of the projects listed in this file, which are organized by general thematic.

Project: Role of the sea for assessing precipitation rates at 2100 on local scales

Keywords: climate change, sea-atmosphere coupling, severe events

Description:

Forecasting precipitation several days in advance remains a significant challenge in meteorology, particularly when it comes to extreme events that require sub-kilometric resolutions to capture their spatio-temporal details. Our research group has extensively explored these model difficulties and successes, as documented in a series of papers utilizing the WRF weather model.

In this project, we aim to investigate **the role of the sea** as a trigger for severe precipitation events. To achieve this, we will employ AI-based architectures to establish a mapping that links features from climate models (such as sea-surface temperature, pressure, and other meteo-marine fields) to observed reality. The climate models will be sourced from the EURO-CORDEX ensemble, covering future climate conditions under various RCP climate change scenarios. The study area will encompass the entire Europe.

The observed reality, or "truth," will be represented by spatially distributed precipitation data from the NASA-IMERG network (see figure). We will utilize 20 years of hourly-cumulated precipitation data on a 10-km grid, spanning from 2002 to 2022, to train and test our AI architecture. Additionally, rain-gauge data from the last 20 years for the Italian territory, provided by Arpal within the ongoing AIxtreme project funded by the Compagnia di San Paolo, will complement this information.

This data will enable us to study how sea-induced mechanisms can trigger severe precipitation, enhancing our understanding and forecasting capabilities for such extreme events. By integrating high-resolution climate models with detailed observational data through advanced AI techniques, we aim to develop more accurate predictive models that can anticipate severe weather patterns and their impacts more effectively.

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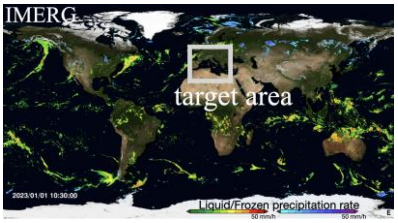
Figure: Example of precipitation detection from the NASA-IMERG detection system



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Project: Treatment of agro-industrial wastewaters using microalgae

Keywords: photobioreactors, new plant development, microalgal biomass exploitation, lipid recovery

Description:

The increasing of urbanization and industrialization leads to the production of large quantities of wastewater around the world. Part of this waste can be exploited for the growth of microalgae, reducing their cultivation costs, and making chemicals recovery and biofuel production more feasible.

Using the mixotrophic metabolism, microalgae are able to absorb and use many of the organic molecules contained in wastewater, reducing its polluting load, leading to the production of additional microalgal biomass and to the purification of the water used.

After the growth, the microalgae biomass can be collected and used for the production of biofuels and for the recovery of chemicals of interest.

Batch and continuous microalgal growth systems are available in the laboratory of the research group. By means of these plants, wastewater (e.g.: olive mill and winery wastewaters, landfill leachate, sewage wastewaters, etc.) will be micro-phytotrophically treated and then analysed.

An *ad hoc* plant for the growth and the collection of microalgae in wastewaters will be studied and tested, reaching the goal to work in a full continuous mode. A pumping system, operating with variable flow rates, will be carefully developed to make the device less energy intensive and to reduce the hydraulic retention time. Downstream of the cultivation system, a plant will be designed for microalgal biomass settling, and the microalgal biomass will be collected using new methodologies, such as electro-coagulation.

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Project: Ecomorphodynamics of coastal tidal environments

Keywords: Saltmarshes, biodiversity, morphodynamics, tides, sea-level rise

Description: Tides, storms, rising sea level due to climate change and sediment availability are the main features governing the dynamics of tide dominated coastal areas environments such as estuaries and lagoons. In particular, concerns about an increasing sea level and the related ability of intertidal areas to maintain their intrinsic characteristics have deserved a considerable attention in the last years. One of the issues that this project aims to determine the effectiveness of the natural based solution interventions in salt marshes by evaluating the flood risk reduction using a simplified numerical morphodynamic models involving biodiversity indicators and sediment transport parameters.

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Project: Sea-state monitoring trough GNSS onboard a ship

Keywords: Global Navigation Satellite System (GNSS), sea-state monitoring, Amerigo Vespucci ship

Description:

Different measuring systems can provide real-time data on the sea condition in space and time, to be employed for the development of algorithms for the short-term forecast of sea conditions. The present research project proposes to study the sea conditions based on Global Navigation Satellite System (GNSS) observations acquired on School Ship Amerigo Vespucci during its world tour (July 2023 – February 2025). The Geomatics Laboratory of DICCA, with cooperation of DITEN, thanks to the Sea Study Centre (Genoa University), Hydrographic Institute and Italian Navy, has designed and realized the installation of three GNSS receivers and a meteorological station, that are collecting data at different heights onboard of the Amerigo Vespucci mission around the world. The overall objective of the scientific project is the creation of a DataBase (DB) of GNSS and meteorological observations that can be useful to evaluate sea conditions during navigation. The challenging aspects of the proposed project concern the various and possibly severe sea and weather conditions (e.g., Cape Horn passage) to which the instrumentation is exposed and the individuation of the optimal processing technique to separate the ship and the sea movements with adequate accuracy and reliability.

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Figure:

Project: Computing Optimization and Open Science for Coastal and Maritime Downstream Applications

Keywords: Cloud Computing; Big Data; Downstream Applications; Open Science; Coastal; Maritime; FAIR

Brief Description:

The project focuses on optimizing cloud computing technologies to support downstream applications and promote open science initiatives in coastal and maritime climates. These regions face unique environmental challenges, requiring efficient and effective management of vast amounts of data generated from instruments, satellite imagery, and numerical models, among others.

The primary goals of this research are to develop robust frameworks and algorithms that enhance the performance of cloud-based systems in processing and analyzing environmental data. By doing so, the project aims to facilitate more accurate climate modeling, improve environmental monitoring, and support sustainable decision-making processes. Furthermore, the project will emphasize the principles of open science, ensuring that data, tools, and results are accessible and reusable by the broader scientific community.

Key objectives include:

- Data Integration and Management: Create methods for seamless integration and management of heterogeneous datasets from coastal and maritime sources within cloud environments.
- Optimization Algorithms: Develop and optimize algorithms for efficient data processing, storage, and retrieval to support real-time analytics and predictive modeling.
- Support for Downstream Applications: Design cloud-based solutions that cater to specific downstream applications such as disaster management, coastal erosion monitoring, and marine biodiversity conservation.
- Open Science Frameworks: Implement open science practices by developing tools and platforms that ensure transparency, reproducibility, and accessibility of research data and methodologies.
- Scalability and Sustainability: Ensure that the cloud computing solutions are scalable and sustainable, capable of handling increasing data volumes and evolving environmental challenges.

This project will bridge the gap between advanced cloud computing technologies and practical environmental applications, fostering a collaborative scientific environment.

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Relevant links: meteocean.science

Project: The wind-induced bias and adjustment of disdrometer measurements

Keywords: Precipitation, Measurement, Accuracy, Drop size distribution, Wind

Brief Description:

The ocean is the largest recipient of fresh water from the atmosphere, with 80% of global precipitation reaching the ocean surface. The transfer of water from evaporating regions to precipitating regions is the fundamental driver of the global water cycle and influences the large-scale circulation of the atmosphere. In addition to atmospheric effects, rain is also a key component of the ocean surface density due to the freshwater input that reduces its salinity, resulting in strong density gradients. These gradients affect vertical mixing and horizontal advection, which are among the main drivers of ocean circulation.

However, due to the complexity of the marine environment, precipitation data over the oceans are scarce and rely on measurements from ship-based rain gauges or a small number of instrumented buoys. Precipitation data from remote sensing and/or radar platforms still require calibration and validation using surface-based measurements. Non-catching precipitation gauges (NCGs), including disdrometers, can significantly improve the quality and reliability of precipitation data, especially in marine environments with strong winds, sea spray and wave-induced motion.

Indeed, NCGs have a few advantages over the more common (traditional) catching-type gauges, including the ability to provide a wider range of information than just precipitation intensity, such as drop size distribution, visibility and more. In addition, the lack of moving parts and reduced maintenance requirements make them particularly suitable for automatic weather stations in harsh conditions.

The research project aims to fill knowledge gaps in various aspects of precipitation measurements and their use in hydrological modelling and climate studies. It focuses first on assessing the accuracy of disdrometer measurements with respect to wind effects and instrumental biases and developing a suitable disdrometer correction method (DCM). Then, since the collection efficiency of traditional catching gauges is controlled by the DSD through the catch ratios associated with monodisperse rainfall events, the corrected DSD will be used to derive adjustments for measurements obtained from traditional catching gauges. Real-world data from field test sites in Italy and abroad will be analysed to compare the adjusted rainfall with the reference rainfall, thus validating the DCM with observed rainfall and wind time series at different aggregation scales.

The results will allow to assess the impact of using corrected rainfall intensity and DSD data on estimating measurement biases due to environmental conditions, evaluating weather radar estimates, improving statistical analysis of rainfall time series at climatological scales, investigating joint rain and wind climatology features at selected test sites, deriving extreme rainfall event statistics and trends.

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Project: Coastal Flooding hazard under present conditions and in the framework of future climate change

Keywords: Coastal flooding; Wave storm; Extreme levels; Climate Change

Brief Description:

Coastal erosion and coastal flooding are the main hazard for the management of the coastal zone and could pose many disruptions to different human production activities. A detailed knowledge of the processes and on the intensity of the phenomenon it is crucial to provide managing authorities and institutions, and economic stakeholders, the necessary information and scenarios for decision making and policies development.

The research projects will develop a methodological approach suitable for the definition and estimation of extreme levels of coastal flooding due to different physical processes such as wave run-up and set-up, storm surge and long-term sea-level variation due to climate change. The research activities will consist in developing a suitable numerical model suite for the description of wave storms in the coastal region, giving insight of wave run-up and set-up processes, the characterization of storm surge levels and the use of sea level variation projections under different Shared Socioeconomic Pathways (SSPs) for mid and end of the century (2050 & 2100). After developing a wide dataset of metocean forcings the analysis of flooding processes will be carried out through the employment of process based numerical models, having as the final objective of the project the evaluation of return levels for coastal inundation areas along the coastline of the Mediterranean Sea with specific attention to hot spot with respect to coastal infrastructures, lowlands and populated areas.

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Project: Wave energy Exploitation by means of standard leisure boat mooring device: a comprehensive research

Keywords: Wave energy exploitation; Floating buoy; Wave Flume; CFD

Brief Description:

Wave energy exploitation is a one of the most promising goals that should be reached in order to increase the possibility of renewable energy sources in the framework of the UN Sustainable Development Goals for 2030 (goals 7, 11 and 13). The research projects will explore an innovative device for wave energy extraction, based on simple and well-established physical principles and low cost device. In particular it will be explored the feasibility of a PTO system embedded in a common floating buoy used for leisure boat mooring operations.

The activity of the project will involve some preliminary test in the DICCA wave flume with regular and irregular waves in order to monitor and test the system working principles and the eventual production of electric energy. Hence CFD simulations will be developed on the basis of SPH numerical models in order to optimize the geometry and the response of the floating device on the basis of specific wave climate in order to optimize the capacity factor of the device based on local wave information (Gulf of Genoa). Finally, a field test of the device will be carried out monitoring the behavior of the buoy in real sea conditions either from a dynamic point of view either for the PTO system.

The aim of the project is to increase the TRL of the device from level 2 to level 6 or 7 in order to test the feasibility of the energy exploitation system and its reproduction for a large-scale application.

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Relevant links: meteocean.science