PhD Program in Civil, Chemical and Environmental Engineering
Curriculum in Fluid Dynamics and Environmental Engineering

June 2026 Call, XLII cycle - Starting date: November 1 st 2026

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 thematics. Click on the Thematic you are interested in to see the full list of projects.

Projects in Fundamentals of Fluid Mechanics

Projects in Environmental Fluid dynamics, morphodynamics and climate changes

Projects in Hydrodynamics and Morphodynamics of Rivers, Coasts, Estuaries and Lagoons

Projects in Hydrology and Water Resources Management

Projects in Biological Fluid Dynamics

Projects in Geomatics

Other Projects

Projects in Fundamentals of Fluid Mechanics

Project: The Self-Sustaining Process of Turbulence over a LIS Surface

Project: Fragmentation Dynamics of Slender Fibres in Turbulence

Project: Electro-fluid-structure interaction of artificial stems and canopies

Project: Design and fabrication of micro fluidic chips

Link to first page

Thematic: Fundamentals of Fluid Mechanics

Project: The Self-Sustaining Process of Turbulence over a LIS Surface

Keywords: Self-Sustaining Process (SSP), Lubricant Impregnated Surfaces (LIS), Weakly nonlinear analysis, DNS

Brief Description:

The self-sustaining process (SSP) of turbulence describes how turbulent flow continuously regenerates itself through the interaction of vortices, streaks, and instabilities near a wall. Streamwise vortices create low- and high-speed streaks, which become unstable and "burst", generating new turbulent structures. These structures in turn regenerate the vortices, maintaining turbulence even in the absence of external disturbances.

Lubricant-Impregnated Surfaces (LIS) are textured or porous materials infused with a lubricating liquid that creates a smooth surface. These surfaces can strongly reduce drag, contamination, icing, and biofouling by minimizing direct contact between the solid substrate and the external fluid. LIS are therefore promising for naval, marine, biomedical, and energy applications where low friction and surface durability are essential. They are often also called SLIPS (Slippery Lubricant Infused Porous Surfaces) but they are not slippery, despite common belief, and the reason for the reduction in skin friction drag must likely be searched elsewhere.

The objective of the present thesis is to explore how the near-wall SSP is modified by a wall which is not a conventional no-slip wall. We expect the presence of a mobile lubricant interface to modify the near-wall boundary condition, introducing partial slip and reducing wall shear stress. As a result, the generation and amplification of near-wall vortices and streaks can be weakened, potentially disrupting the classical regeneration cycle that sustains turbulence. Depending on lubricant retention, interface deformability, and possible bubble formation, LIS may therefore attenuate turbulence production and reduce drag, although depletion and interfacial instabilities can also lead to more complex flow behaviors.

The thesis will explore this issue, starting with a weakly nonlinear framework pioneered by the PI of the proposal and collaborators (J. O. Pralits, S. Cherubini and A. Bottaro, "Weakly nonlinear optimal perturbations", *Journal of Fluid Mechanics*, vol. 785, pp. 135–163, 2015. DOI: 10.1017/jfm.2015.622). After this stage is properly understood, nonlinear direct numerical simulations will be conducted to corroborate the findings and provide understanding of the large amplitude phases. The latter part of the work will be conducted in collaboration with Prof. Stefania Cherubini of the Politecnico di Bari.

Finally, depending on the "taste" of the selected candidate, a possible involvement in parallel experiments conducted on a Taylor-Couette apparatus in Genova can be envisaged.

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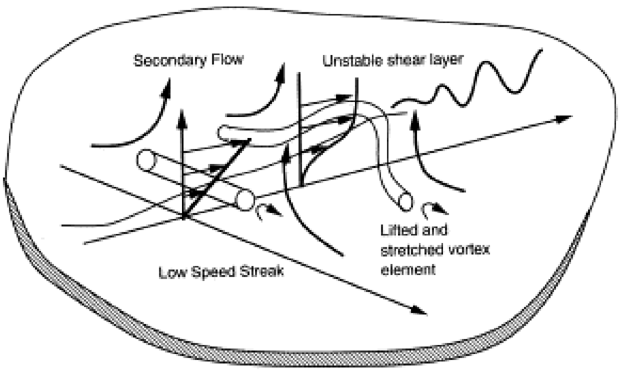
Relevant links: http://www.dicat.unige.it/bottaro/research.html

Figure: overview of the bursting process, one of the building elements of the SSP (R.L. Panton, "Overview of the self-sustaining mechanisms of wall turbulence", *Progress in Aerospace Sciences*, 37 (4), pp. 341-383, 2001. DOI : 10.1016/S0376-0421(01)00009-4.)



Link to the list of projects

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Thematic: Fundamentals of Fluid Mechanics

Project: Fragmentation Dynamics of Slender Fibres in Turbulence

Keywords: Turbulence, Fragmentation, DNS, Microplastic.

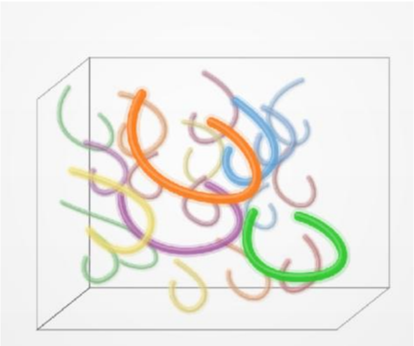
Brief Description:

This PhD project will develop theoretical and reduced-order models for the fragmentation of slender fibres in turbulence. The starting point is the kinetic theory recently proposed by A. Mazzino (JFM, 2026) for inertial-range fibre fragmentation. The project will investigate how turbulent velocity increments generate bending loads, curvature fluctuations and rupture probabilities along finite-size fibres. A central goal is to connect turbulent stress histories with population-balance descriptions of the evolving fragment-size distribution. The work will distinguish eddy-time-limited breakup from rare-event fragmentation below critical material and flow-dependent spans.
Special attention will be given to intermittency corrections, arrest lengths and the transition between active fragmentation and mechanically stable fragments.
The theory will be extended to include stochastic waiting times, fatigue-like accumulation and non-ideal daughter-size distributions.
Reduced numerical models will be used to test the resulting kinetic closures over parameter ranges relevant to environmental microfibres. The expected outcome is a predictive framework linking turbulence statistics, fibre mechanics and fragment population dynamics.
The project will contribute to the physical understanding of how elongated microplastic fibres evolve in turbulent aquatic environments.

Referent: Andrea Mazzino (andrea.mazzino@unige.it)

Relevant links: https://www.cambridge.org/core/journals/journal-of-fluid-mechanics/article/turbulenceinformed-kinetic-theory-of-inertialrange-fibre-fragmentation/F383A87AD1C8DA4823E7E539DFE0A3AA

Figure: Sketch of flexible fibres in turbulence



Link to the list of projects

Thematic: Fundamentals of Fluid Mechanics

Project: Electro-fluid-structure interaction of artificial stems and canopies

Keywords: energy harvesting, flow control, high-fidelity numerical simulation

Brief Description:

The idea of extracting energy from environmental flows using fluid-structure interaction (FSI) has been driving a significant research activity for the last decades, typically with the goal of supply low-power sensors deployed in remote or hazardous environments [1]. Following such aim, this project will investigate the potential of using transversely clamped, elastic plates combined with a suitable electro-mechanical coupling (e.g., piezoelectric transduction) to harvest the kinetic energy of representative wall-bounded fluid flows. In fact, such a concept has been considered by a few recent studies in rather simplified flow conditions [2,3]. The need of tackling the problem in a more complex and realistic setting emerges, in particular, when envisioning to assemble numerous plates into an 'artificial canopy' to magnify the extracted power and eventually exploit cooperative effects caused by nonlinear interactions among many devices. In addition, the same framework can be explored from the perspective of controlling the flow properties (e.g., mixing enhancement or depletion).

Objectives driving the planned research will be: (i) to isolate the dominant mechanisms and dynamical regimes that can emerge as a function of the key electro-mechanical parameters involved in the problem; (ii) to devise useful indications for optimal energy conversion efficiency based on the informed and appropriate choice of such governing parameters; (iii) to understand if and how a dense ensemble of piezoelectric stems can effectively enhance the energy extraction and/or flow control capabilities. From a methodological viewpoint, we will employ high-fidelity direct numerical simulations, using an immersed boundary method to enforce the two-way coupling between the flow and the structure, as well as reduced order models to rationalize our findings and pave the way for the design of novel energy harvesting or flow control devices.

BIBLIOGRAPHY

[1] McCarthy, J. M., Watkins, S., Deivasigamani, A., & John, S. J. (2016). Fluttering energy harvesters in the wind: A review. *J. Sound Vib.*, 361, 355-377.

[2] Zhu, Q. (2024). Constructive interaction in an array of flexible energy-harvesting plates in oscillatory cross flow. *Phys. Rev. Fluids*, 9(7), 074101.

[3] Zhang, J., & Nakamura, T. (2026). Energy conversion and dynamics of an inclined thin flexible plate in oscillatory flows. *J. Fluid Mech.*, 1032, A44.

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Link to the list of projects

Thematic: Fundamentals of Fluid Mechanics

Project: design and fabrication of micro fluidic chips

Keywords: microfluidic chips; mathematical modelling; carriers production

Brief Description:
Microfluidics is a rapidly evolving field that focuses on the manipulation of fluids at the micrometre scale, enabling precise control over fluid behaviour, mixing processes, and interface formation. A key advantage of microfluidic technology is its versatility, as microfluidic chips can be tailored in terms of geometry, architecture, and material composition to meet specific application requirements. Owing to their precision, efficiency, and flexibility, microfluidic systems have emerged as powerful tools for the synthesis of a wide range of carrier systems, including emulsions, liposomes, hydrogel beads, and polymeric nanoparticles. These carriers are of considerable interest across diverse sectors, such as agriculture, food, cosmetics, biomedicine, pharmaceuticals, and environmental engineering, where particle size, monodispersity, and structural uniformity are critical performance parameters. Furthermore, the study of microscale flow phenomena within microfluidic devices can provide valuable insights for the development of digital twins and predictive models, enabling the properties of the generated products to be anticipated and optimized prior to fabrication. This PhD project will focus on the design and fabrication of microfluidic chips capable of producing a variety of micro- and nanoscale systems with high reproducibility and tunable characteristics. The research will integrate experimental investigations with mathematical modelling to deepen the understanding of the fluid dynamics and formation mechanisms governing product generation, ultimately supporting the development of predictive tools and the optimization of microfluidic device performance.

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Link to the list of projects

Projects in Environmental Fluid dynamics, morphodynamics and climate changes

Project: Hybrid Modelling with AI for Air-Quality Forecasting

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Thematic: Projects in Environmental Fluid dynamics, morphodynamics and climate changes

Project: Hybrid Modelling with AI for Air-Quality Forecasting

Keywords: Pollution, Weather Models, Forecasts, AI-based methods

Brief Description:

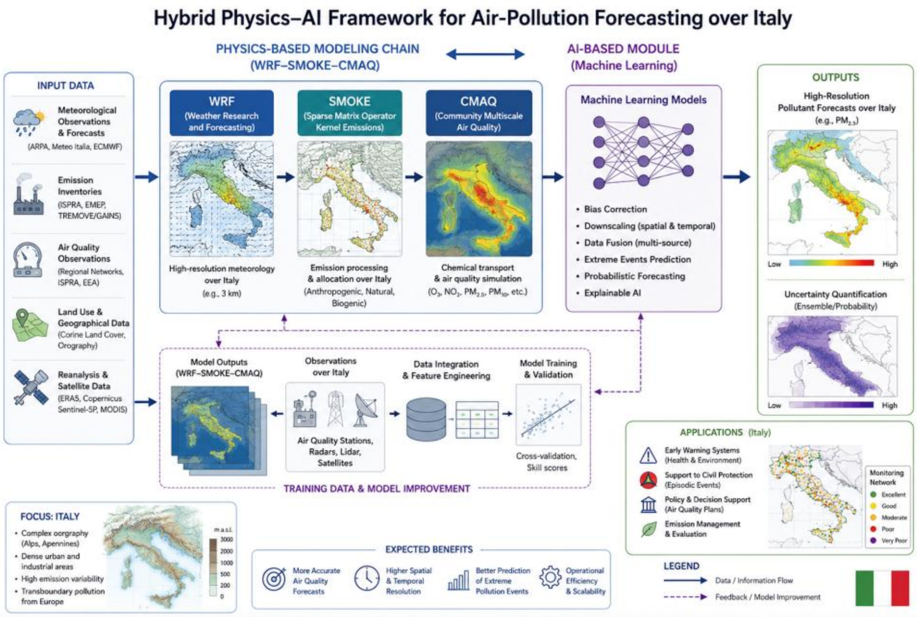
This PhD project will develop hybrid physics-based and AI-based methods for air-pollution forecasting. The starting point is the coupled use of WRF for meteorology, SMOKE for emission processing, and CMAQ for chemical transport simulations. The project will investigate how meteorological uncertainty, emission variability and chemical nonlinearities affect the prediction of pollutants such as ozone, nitrogen oxides and particulate matter.

A central goal is to improve forecast accuracy by combining deterministic model outputs with machine-learning correction, downscaling and data-fusion techniques. AI methods will be trained using observations from ground monitoring networks, meteorological reanalyses, emission inventories and outputs from WRF–SMOKE–CMAQ simulations. Special attention will be devoted to bias correction, extreme-pollution episodes and the propagation of uncertainty from weather forecasts to air-quality predictions. The project will also explore reduced-order and surrogate models able to accelerate computationally expensive chemical-transport simulations.

Case studies will focus on urban and regional pollution episodes where meteorology strongly controls pollutant accumulation, dispersion and chemical production. The expected outcome is an operationally oriented framework for more accurate, interpretable and computationally efficient air-quality forecasts. The project will contribute to environmental monitoring, public-health warning systems and decision-support tools for pollution mitigation.

Referent: Andrea Mazzino (andrea.mazzino@unige.it)

Figure: Sketch of the project idea



Link to the list of projects

Projects in Hydrodynamics and Morphodynamics of Rivers, Coasts, Estuaries and Lagoons

Project: Numerical modeling of wave mitigation induced by seagrass meadows

Project: Direct Numerical Simulation of Sediment Transport and Sand Bedform Initiation Under Shallow Non-Breaking Free-Surface Waves

Project: Experimental observations on tidal bifurcations stability

Project: Bedform Development in Submarine Canyons: Investigating the Interaction Between Turbidity Currents and the Erodible Seabed

Project: Geo-Hazard of Turbidity Currents on Underwater Infrastructures

Link to first page

Thematic: Projects in Hydrodynamics and Morphodynamics of Rivers, Coasts, Estuaries and Lagoons

Project: Numerical modeling of wave mitigation induced by seagrass meadows

Keywords: nature-based solutions, canopy flow, numerical simulation, wave models

Brief Description:

The proposed research topic regards the study of the potential of seagrass meadows for coastal protection and inherent environmental processes. In this context, it can be noted a recent trend focusing on 'nature-based' solutions (NBSs), motivated by advantages such as ecological compatibility and economic viability with respect to so-called 'grey' engineering approaches [1]. A more strategic employment of seagrass as an efficient NBS, however, requires to better understand how the wave mitigation potential depends on main physical parameters such as local water depth, wave characteristics, sparsity, submergence and growth rate of the canopy. In addition, the problem involves the resistance of seagrass meadows to uprooting.

Here, we plan to address these issues blending a fundamental fluid-structure interaction perspective with a more applied coastal engineering one. On the fundamental side, high-fidelity numerical simulations of turbulent flows over flexible canopies will be carried out considering canonical configurations which are representative of the smaller scale problem, thus obtaining accurate predictions of key quantities such as drag coefficient and diffusive fluxes [2]. On the applied side, we will perform broader-scale simulations of wave propagation using 'phase-resolving models' in which the influence of the seagrass meadow will be informed by results from the high-fidelity computational framework [3]. The developed tool will be tested with respect to suitable areas in the Tyrrhenian Sea, aiming at significantly improving the accuracy of simulative predictions compared to the state of the art.

BIBLIOGRAPHY

[1] Morris, R. L., Konlechner, T. M., Ghisalberti, M., & Swearer, S. E. (2018). From grey to green: Efficacy of eco-engineering solutions for nature-based coastal defence. *Global Change Biology*, 24(5), 1827-1842.

[2] Monti, A., Olivieri, S., & Rosti, M. E. (2023). Collective dynamics of dense hairy surfaces in turbulent flow. *Scientific Reports*, 13(1), 5184.

[3] Lira-Loarca, A., Cáceres-Euse, A., De-Leo, F., & Besio, G. (2022). Wave modeling with unstructured mesh for hindcast, forecast and wave hazard applications in the Mediterranean Sea. *Applied Ocean Research*, 122, 103118.

Referents: Francesco De Leo (francesco.deleo@unige.it) and Stefano Olivieri (stefano.olivieri@unige.it)

Link to the list of projects

Thematic: Projects in Hydrodynamics and Morphodynamics of Rivers, Coasts, Estuaries and Lagoons

Project: Direct Numerical Simulation of Sediment Transport and Sand Bedform Initiation Under Shallow Non-Breaking Free-Surface Waves

Keywords: wave boundary layer, Two-phase flow, Turbulence, Seabed instability, Coastal transport process

Brief Description:

Sand bedforms generated beneath surface gravity waves play a central role in coastal morphodynamics, sediment redistribution, and near-bed hydrodynamics. Despite their importance, the physical mechanisms controlling their onset under shallow, non-breaking free-surface waves remain only partially understood, especially when the wavelength is sufficiently large for turbulence to develop beneath both wave crests and troughs. This PhD project aims to investigate the origin of sand bedforms and the coupled dynamics of wave-induced turbulence and mobile sediment using direct numerical simulation (DNS).

The project will build on an existing highly efficient flow solver based on a pseudo-spectral numerical scheme, written in C, which has recently enabled the first DNSs of shallow non-breaking free-surface waves over a wavy fixed bottom. The successful candidate will contribute to extending this framework by developing and implementing a solid-phase solver for sediment transport. The sediment will be modelled using an Eulerian continuum approach, in which the granular phase evolves as a continuum solid phase and is two-way coupled with the fluid motion. This formulation will allow the simulation of feedback mechanisms between turbulence, sediment concentration, bed deformation, and wave-induced stresses without relying on empirical closure models for the near-bed flow. The research will focus on identifying the instability mechanisms leading to bedform initiation, quantifying sediment fluxes under oscillatory turbulent boundary layers, and clarifying the role of wave-induced turbulence in shaping the early stages of bedform growth. The project combines fundamental fluid mechanics, high-performance numerical modelling, and coastal sediment transport physics.

Applicants should have strong skills in fluid dynamics and scientific programming. Experience with C programming, numerical methods for partial differential equations, and data analysis is expected. Knowledge of parallel computing is desirable, while previous experience on high-performance computing facilities would be a plus.

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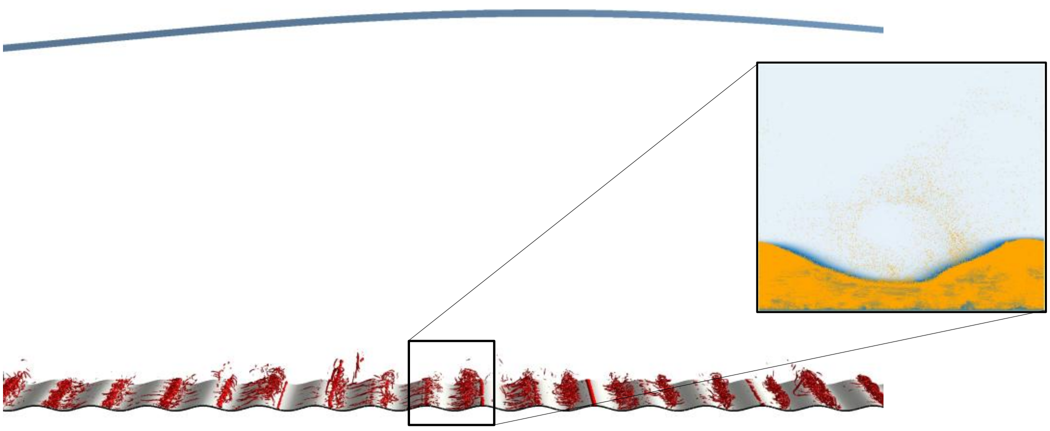

Figure: Turbulent vortices shed by ripples under wave crest; inset: from sediments to concentration field.

Link to the list of projects

Thematic: Projects in Hydrodynamics and Morphodynamics of Rivers, Coasts, Estuaries and Lagoons

Project: Experimental observations on tidal bifurcations stability

Keywords: tidal channels, experiments, bifurcations

Brief Description: Tidal networks are characterised by bifurcating channels. While the issue of bifurcation has been extensively studied in the riverine literature, the case of tide-influenced bifurcation remains less understood. Some theoretical approaches have addressed river bifurcation under weak tidal influence of small amplitude, while numerical simulations have been carried out to investigate the morphological evolution of bifurcations in deltas influenced by tides. The project wishes to experimentally investigate the evolution of a fully tidal-influenced bifurcation in a laboratory model of a straight tidal channel with varying width.

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Link to the list of projects

Thematic: Projects in Hydrodynamics and Morphodynamics of Rivers, Coasts, Estuaries and Lagoons

Project: Bedform Development in Submarine Canyons: Investigating the Interaction Between Turbidity Currents and the Erodible Seabed

Keywords: turbidity currents, sediment transport, submarine geohazard, underwater infrastructures, numerical modelling

Brief Description:

The aim of this PhD fellowship is to investigate the formation and evolution of bedforms within submarine canyons generated by sediment gravity flows, particularly turbidity currents. These flows constitute a severe geohazard to offshore infrastructure, including pipelines and telecommunication cables, owing to their capacity to attain velocity in excess of 5 m/s and to travel over distances of several tens of kilometers. Numerous documented events have demonstrated their destructive potential, including pipeline displacement and berm damage offshore the Philippines, as well as cable failures near Hawaii, Taiwan, Réunion and within the Congo Canyon. Such incidents can result in substantial service disruption, complex and costly repair operations, and far-reaching economic and societal consequences.

Given the considerable challenges associated with direct in situ measurements of sediment gravity flows, current understanding of their dynamics is derived largely from scaled laboratory experiments and numerical investigations. However, significant knowledge gaps remain regarding the mechanisms governing seabed erosion, deposition, and bedform development associated with turbidity currents.

In response to these challenges, this PhD research project involves a comprehensive and systematic investigation of the complex interactions between turbidity currents and the erodible seabed. The research will combine advanced numerical modelling with the analysis of an extensive dataset of high-resolution seabed surveys acquired at multiple time intervals and made available by the industrial sponsor. The numerical model will be employed to simulate both the dynamics of sediment gravity flows and the associated morphological evolution of the seabed, enabling detailed examination of bedform initiation, migration, and preservation. By integrating model predictions with repeated seabed observations, the project will improve understanding of the processes controlling submarine bedform development and provide new insights into the assessment and mitigation of risks posed by sediment gravity flows to critical offshore infrastructure.

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Relevant links: www.weatherwatersand.com

Link to the list of projects

Thematic: Projects in Hydrodynamics and Morphodynamics of Rivers, Coasts, Estuaries and Lagoons

Project: Geo-Hazard of Turbidity Currents on Underwater Infrastructures

Keywords: turbidity currents, sediment transport, submarine geohazard, underwater infrastructures, numerical modelling

Brief Description:

The aim of this PhD fellowship is analysing the impact of turbidity currents on underwater infrastructures. Turbidity currents are sediment gravity flows that, once initiated, can traverse considerable distances, spanning hundreds to thousands of kilometres into the deep ocean, and reach velocities as high as 20 m/s (Piper et al., 1999). The potential consequences for infrastructure along their path are severe, as demonstrated by the impact on the submarine cable sector dating back to the installation of the first transatlantic cables, notably during the 1929 Grand Banks earthquake and other subsequent events. Recent cable displacements and ruptures in Taiwan's Gaoping Canyon and in the Congo Canyon serve as a stark reminder of this ongoing risk faced by offshore facilities (Carter et al., 2012; Talling et al., 2022). Amid the rapid expansion of submarine telecommunication and power cables, offshore oil & gas projects, scientific monitoring experiments, deep-sea mining, and renewable energy initiatives since the 1990s, the exposure of seafloor infrastructures to storm-induced turbidity currents becomes an increasingly significant geo-hazard that demands effective management strategies. Coupled with the increased exposure associated with the growth of offshore infrastructure installations, trends in climate change indicate that a warming ocean could lead to the development of larger and stronger cyclonic storms (Emanuel, 2003). Understanding the effect of stronger storms on coastal climate on the frequency and magnitude of turbidity currents is a topic that remains largely unknown.

In response to these challenges, this PhD research project involves a comprehensive and systematic investigation of the complex interactions between storms, triggering and development of deep-sea sediment gravity flows. The project's multi-faceted approach starts with the analysis of synthetic tropical cyclone databases, enabling controlled studies even in regions with limited historical data, such as those at the edges of cyclone basins. This approach combines the benefits of using global climate models and synthetic modelling to generate future climate synthetic tropical typhoons spanning hundreds of years (Bloemendaal et al., 2022). Parametric relations for cyclonic wind and pressure fields will be employed to extract site-specific data from these databases, while refined parametric formulas for cyclone-induced waves and storm surges will provide crucial information on wave and water level conditions across selected study sites. The analytical wind field formulation will be calibrated through the results of high-resolution simulations of typhoons performed in selected areas of interest.

The outcome of this research project will aid in developing targeted mitigation strategies, enhancing the resilience of energy and telecommunication networks, discriminating between natural and anthropogenic risks for underwater infrastructures, and supporting sustainable coastal and offshore development in storm-prone areas, paving the way for sustainable development and climate adaptation in the face of increasing cyclonic activities and sea level rise.

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[Link to the list of projects]

Projects in Hydrology and Water Resources Management

Project: Climatology of intense short-duration rainfall in Mediterranean region

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Thematic: Hydrology and Water Resources Management

Project: Climatology of intense short-duration rainfall in Mediterranean region

Keywords: Rainfall statistics, climate change, short duration extremes, storm characteristics, non-asymptotic statistics

Brief Description:

The project seeks to analyze historical precipitation records collected at high temporal resolutions (1–10 minutes) in order to characterize their statistical properties and identify storm patterns. The ultimate goal is to develop a methodology for defining design events used in hydraulic hazard assessment and in the planning and design of hydraulic infrastructure for small Mediterranean coastal catchments. The project also involves the application of advanced statistical approaches, such as the Metastatistical Extreme Value Distribution, which enables the evaluation of statistical non-stationarity and the quantification of potential climate change impacts.

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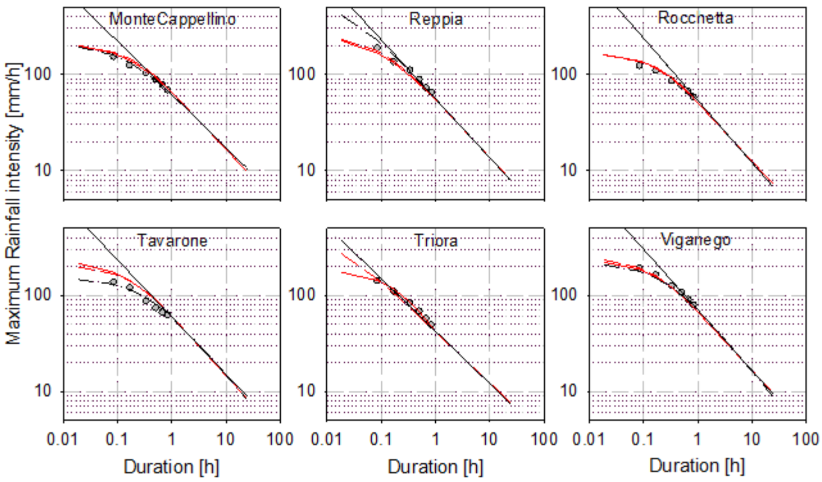

Figure: Comparison between different IDF equations and the empirical quantile assessed for selected short-duration rainfall at 10-years return period.

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Projects in Biological Fluid Dynamics

Project: Virtual surgery of the human nose via computational fluid dynamics

Project: Blood flow in the choroid

Project: In vivo measurements of vitreous humour mechanical properties

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Università di Genova | **DICCA** Ph.D. PROGRAM IN CIVIL, CHEMICAL AND ENVIRONMENTAL ENGINEERING

Thematic: Biological Fluid Dynamics

Project: Virtual surgery of the human nose via computational fluid dynamics

Keywords: biofluid dynamics, nasal flow, lungs, CFD

Brief Description:

Nasal breathing difficulties (NBD) are as widespread and important as difficult to diagnose, owing to the anatomical complexity and extreme inter-subject variability of the human nose. Surgical corrections are often necessary, but the failure rate of such corrections is extremely high, with e.g. corrections of septal deviations failing in more than 50% of the cases. Computational Fluid Dynamics (CFD) is emerging as a powerful tool to diagnose NBD and to plan/evaluate strategies for surgical corrections beforehand. However, for the pre-operative (pre-op) anatomy to be compared with the outcome of virtual surgery (post-op), one has to answer some fundamental questions: How shall the comparison be carried out?; How can well-being of a correctly functioning nose be measured or evaluated from a simulation?; How can such results be shared and communicated to the medical community? This topic is part of an ongoing collaboration with the polytechnical school of Milan and the Hospital San Paolo in Milan.

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Relevant links: http://www.dicat.unige.it/jpralits/Talks/DIMA/dima-2022.pdf

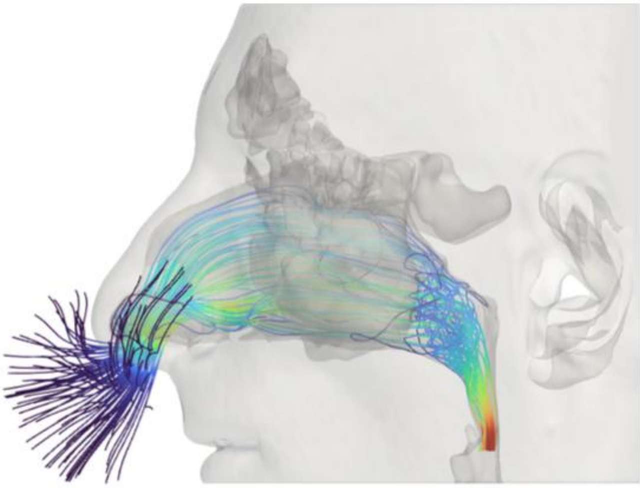

Figure: Streamlines showing the flow during inhaling. Colors show magnitude of velocity; blue is low velocity and red is high velocity.

Link to the list of projects

Thematic: Biological fluid dynamics

Project: Blood flow in the choroid

Keywords: blood flow, venous drainage, pressure control

Brief Description:

The choroid is the most densely vascularised tissue of the human body. It lies between the retina and the sclera in the eye and contributes to providing nutrients to the retina, which is a highly metabolically active tissue. Since the eye is a pressurised organ, the choroidal circulation has some very peculiar characteristics. In particular, various animal experiments have shown that the choroidal venous pressure is tightly related to the intraocular pressure (IOP), and as the latter is artificially increased the choroidal venous pressure increases by the same amount and is invariably a few mmHg higher than IOP [1,2]. Moreover, the choroidal microcirculation and the venous drainage system have unique anatomical features [3]. Abnormal blood flow in choroidal veins and venous congestion are known to be associated with various pathological conditions, such as, in particular, central serous retinopathy [4]. We propose to construct a mathematical model of the choroidal circulation, that accounts for the specific characteristics of the choroidal circulation, with the aim of unravelling the mechanics of this complicated perfusion and drainage system.

References:

[1] Bill, Anders. "Aspects of the Regulation of the Uveal Venous Pressure in Rabbits." *Experimental Eye Research* 1, no. 3 (1962): 193–99.

[2] Mäepea, Olav. "Pressures in the Anterior Ciliary Arteries, Choroidal Veins and Choriocapillaris." *Experimental Eye Research* 54, no. 5 (1992): 731–36.

[3] Spaide, Richard F. "CHOROIDAL BLOOD FLOW: Review and Potential Explanation for the Choroidal Venous Anatomy Including the Vortex Vein System." *Retina* 40, no. 10 (2020): 1851–64.

[4] Cardillo Piccolino, Felice, Alessandro Arrigo, Paolo Forte, et al. "Intraocular Pressure and Ocular Perfusion Pressure in Central Serous Chorioretinopathy." *American Journal of Ophthalmology* 280 (2025).

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Link to the list of projects

Thematic: Biological Fluid Dynamics

Project: In vivo measurements of vitreous humour mechanical properties

Keywords: vitreous humour, viscoelasticity, rheology

Brief Description:

The vitreous humour is the gel contained within the vitreous chamber of the eye. It exhibits viscoelastic properties, which have been measured ex vivo by various authors using classical rheological techniques [1]. However, the vitreous gel has a very delicate structure that is easily disrupted during extraction from the eye, making rheological measurements particularly challenging.

An attractive alternative for studying the mechanical properties of the vitreous body is to use images of vitreous motion induced by eye rotations, combined with a mathematical model, to reverse-engineer the viscoelastic properties of the vitreous. A similar approach was adopted by Piccirelli et al. [2], who fitted an analytical viscoelastic model to MRI-based visualisations of vitreous motion.

In the present project, we propose to go beyond the authors' approach by using image analysis techniques to analyse OCT-based recordings of vitreous dynamics together with refined three-dimensional numerical models of vitreous motion. The aim of the work is to characterise the in vivo properties of the vitreous. This could have important implications for understanding the generation of vitreoretinal tractions, which underlie numerous vitreoretinal diseases.

References:

[1] Tram, Nguyen K., Courtney J. Maxwell, and Katelyn E. Swindle-Reilly. "Macro- and Microscale Properties of the Vitreous Humor to Inform Substitute Design and Intravitreal Biotransport." *Current Eye Research* 46, no. 4 (2021): 429–44.

[2] Piccirelli, Marco, Oliver Bergamin, Klara Landau, Peter Boesiger, and Roger Luechinger. "Vitreous Deformation during Eye Movement." *NMR in Biomedicine* 25, no. 1 (2012): 59–66.

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Link to the list of projects

Projects in Geomatics

Project: Processing of remote sensing images and data fusion for high-resolution mapping of surface soil moisture in densely vegetated and sloping terrain

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Thematic: Projects in Geomatics

Project: Processing of remote sensing images and data fusion for high-resolution mapping of surface soil moisture in densely vegetated and sloping terrain

Keywords: MultiSpectral Images (MSI), Synthetic Aperture Radar (SAR) images, machine/deep learning, field sensor, GIS

Brief Description:
Surface Soil Moisture (SSM) is a fundamental parameter in various research contexts (water balance, precision agriculture, shallow landslide) and it has been identified as an Essential Climate Variable (ECV) by the Global Climate Observing System (GCOS). Monitoring of SSM variations can be carried out through the accurate use of low-cost field sensors, suitably calibrated and distributed across the study areas, and through remote sensing techniques, which automatically analyse wide areas.

Remote sensing products dedicated to estimating SSM (up to ~5–15 cm depth) are derived from MultiSpectral Images (MSI) and Synthetic Aperture Radar (SAR) images. SAR images are often used on flat, bare terrain with sparse vegetated, whilst Sentinel-2 MSI images feature specialized Red Edge bands, making them particularly effective for vegetation monitoring. Moreover, vegetation conditions represent an indirect indicator of soil moisture. This implies that the correlation between reflectance and soil moisture strongly depends on land cover.

This project aims at defining an automatic procedure in a GIS environment for generating high-resolution SSM maps in densely vegetated and sloping terrain through satellite images processing.

In order to ensure the temporal continuity of spatial monitoring using the SSM model, data fusion allows to fill the gaps in MSI-derived data using SAR images, which is unaffected by cloud cover, or with Copernicus or EUMETSAT products, or with data derived from hydrological models. Machine learning or deep learning algorithms allow to improve the SSM model's estimates. Field sensor data are essential for validation.

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Relevant links: https://land.copernicus.eu/en/products/soil-moisture

https://link.springer.com/chapter/10.1007/978-3-031-91141-5_1

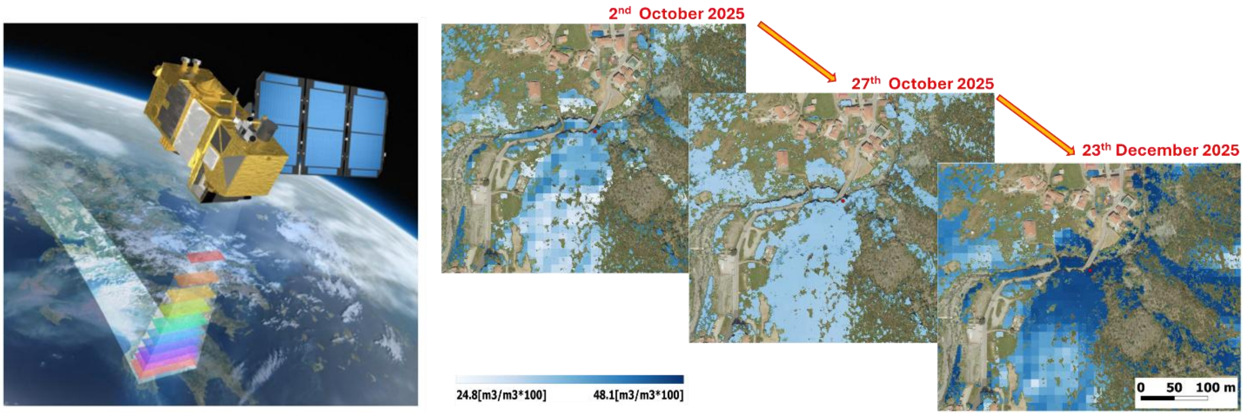

Figure: Example of soil moisture mapping from multispectral satellite images

Link to the list of projects

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Other Projects

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