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

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

The research projects submitted for the admission to the PhD program must be prepared in accordance to 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.

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Projects in Fundamentals of Fluid Mechanics

Project: Incompressible turbulent flow over LIS

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***Thematic*: Projects in Fundamentals of Fluid Mechanics**

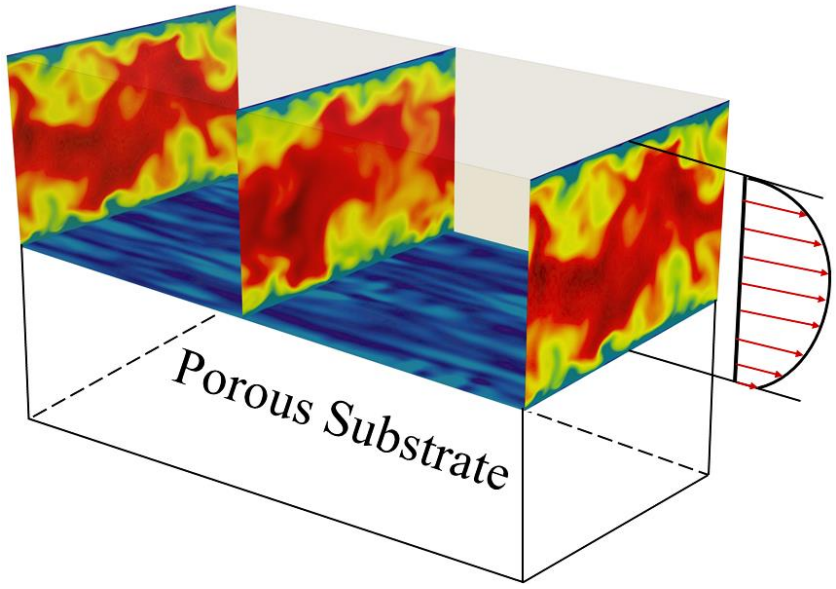
Project: Incompressible turbulent flow over LIS

Keywords: homogenization theory, optimization, numerical simulations

Brief Description:
The motion of a liquid over a lubricant impregnated surface (LIS) is of fundamental and practical importance, because of the lower friction that such surfaces produce when compared, for example, to smooth solid surfaces. This translates immediately into reduced fuel consumption and emissions. Among the problems under scrutiny are (i) the search of the optimal morphology of the porous system which hosts the lubricant, (ii) the identification of optimal lubricant properties, (iii) the study of technologies to replenish the porous layer against losses of the lubricant fluid, (iv) the search of scaling properties of the fluid system against effective boundary parameters. The work to be conducted will consists of the use of multiscale homogenization theory (to infer the effective boundary conditions at a virtual interface between the fluid and the LIS), on the subsequent optimization of the coupled fluid/porous system via direct numerical simulations of the turbulent flow in the liquid layer, and on experiments to be carried out in a dedicated set-up.

Referent: Alessandro Bottaro (alessandro.bottaro@unige.it)

Figure:



Direct numerical simulation of turbulent flow above a porous substrate; the mean streamwise speed (vector plot on the right) exhibits slip at the lower *virtual* wall.

Link to the list of projects

Projects in Environmental Fluid dynamics, morphodynamics and climate changes

Project: Climate models and AI in synergy for assessing precipitation rates at 2100 with unprecedented accuracy

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

Link to first page

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

Project: Climate models and AI in synergy for assessing precipitation rates at 2100 with unprecedented accuracy

Keywords: Climate change, Extreme event forecasts, Artificial Intelligence, Weather models, Non-conventional detection systems

Brief Description:

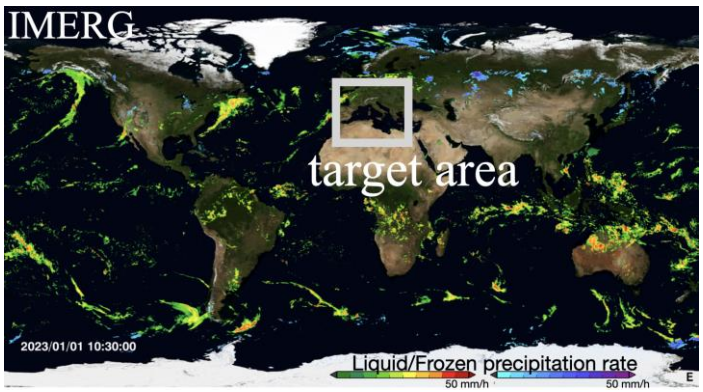
Forecasting several days in advance the precipitation is a major challenge in meteorology, especially in relation to extreme events which require sub-kilometric resolutions to be captured in their spatio-temporal details. Model difficulties and successes have been described in a series of papers of our research group where the WRF weather model was exploited.

In this project, AI-based architectures will be used to find a mapping that connects features from climate models (e.g., temperature, pressure and many other meteorological fields) and the truth. The climate models will be taken from the EURO-CORDEX ensemble of future climate conditions under different climate change scenarios RCP. The area will cover the entire Europe. The truth refers to spatially distributed precipitations form the NASA-IMERG network (see figure). 20 years of hourly-cumulated precipitations, on a 10-km grid, from 2002 to 2022 will be available for the project. These information will serve both to train the AI architecture and for testing purposes. Rain-gauge information will be also used (last 20 years) for the Italian territory. They will be provided by Arpal within the ongoing project AIxtreme funded by the Compagnia di San Paolo.

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

Relevant links: http://www3.dicca.unige.it/mazzino/

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



Link to the list of projects

***Thematic*: Environmental Fluid dynamics, morphodynamics and climate changes**

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

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

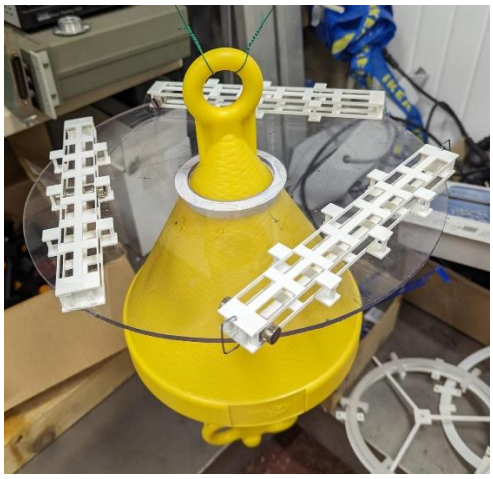
Brief Description:
Wave energy exploitation is a one of the most promising goals that should be reached in order to increase the possibility of renewable energy sources in the framework of the UN Sustainable Development Goals for 2030 (goals 7, 11 and 13). The research projects will explore an innovative 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.

Referents: Giovanni Besio (giovanni.besio@unige.it), Corrado Boragno (corrado.boragno@unige.it)

Relevant links: meteocean.science



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

Project: Evolution and morphodynamic equilibrium of river deltas

Project: Vulnerability and resilience of tidal environments to climate change

Project: Direct numerical simulation of non-breaking waves propagating over a movable bed: sediment transport, bedform evolution and wave attenuation

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

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

Project: Evolution and morphodynamic equilibrium of river deltas

Keywords: Sediment transport, morphodynamics, rivers, deltas, channel network

Brief Description:
River deltas are transitional environments of great economic and ecological value which are widely spread along the coasts of the Earth. Knowledge of the morphodynamic equilibrium of deltaic channel networks is thus of great importance not only for better understanding the response of these systems to autogenic and allogenic controls, but also for management purposes and for assessing the resilience of deltas to changes in external factors, either of natural or anthropogenic origin.

Delta formation is driven by a balance between the constructive forces of water and sediment discharge and the destructive forces of waves and tides. Increasing water discharge, sediment discharge and drainage basin area enhance the probability of a river to form a delta. Conversely, increasing wave height and tidal range counteracts delta formation (Caldwell et al., 2019).

Changes in the intensity and frequency of riverine flooding and storms associated with future climate alterations are likely to dramatically increase the exposure to flooding of a large amount of people living on deltas (Edmonds et al., 2020). Similarly, reductions in sediment flux consequent to changes in land management practices and dam construction, as well as groundwater and hydrocarbon extraction impact strongly delta biogeophysical functioning and affect the long-term sustainability of these landscapes (Tessler et al., 2018; Dunn et al., 2019).

In this PhD project we intend to build up a mechanistic model of tidally dominated delta channel networks in which water and sediment fluxes transported by the various delta branches are connected together through a localized treatment of bifurcations/confluences.

The development of this model will allow us to answer two main research questions. The first addresses how the delivery of water and sediment to a delta can be affected by the tidal forcing and by the network structure of deltaic channels. The second question this project wants to answer concerns the formative discharge that has to be used to estimate the possible equilibrium altimetric configuration of lowland deltas. Finally, the numerical model will be applied to the case study of the Po River Delta where river bed surveys performed at different years are available.

Referents: Michele Bolla Pittaluga (michele.bollapittaluga@unige.it),
Nicoletta Tambroni (nicoletta.tambroni@unige.it)

Link to the list of projects

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

Project: Vulnerability and resilience of tidal environments to climate change

Keywords: Sea level rise, saltmarshes, ecology, lagoon, morphodynamics

Brief Description:
Tides, storms, rising sea level due to climate change and sediment availability are the main features governing the dynamics of tidal environments such as estuaries and lagoons. In particular, concerns about an increasing sea level and the related ability of tidal environments to maintain their intrinsic characteristics have deserved a considerable attention in the last years. One of the issues that this project aims to study is the stability of saltmarshes under different environmental conditions by means of the formulation of proper process-based analytical and numerical models. Ecological implications, such as those related to the growth of halophytic vegetation and the role of benthic biofilms on bed erosion, are considered, as possible natural risk mitigation of coastal and tidal environments.

Referent: Nicoletta Tambroni (nicoletta.tambroni@unige.it)

Relevant links: Tambroni, N., Seminara, G. A one-dimensional eco-geomorphic model of marsh response to sea level rise: Wind effects, dynamics of the marsh border and equilibrium (2012) 117 (3).

https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2012JF002363

Link to the list of projects

***Thematic*: Hydrodynamics and Morphodynamics of Rivers, Coasts, Estuaries and Lagoons**

Project: Direct numerical simulation of non-breaking waves propagating over a movable bed: sediment transport, bedform evolution and wave attenuation

Keywords: Marine hydraulics, Coastal engineering, Turbulence, Wave boundary layer

Brief Description:

Background. When non-breaking wind waves approach the coast and propagate over a shallow sandy seabed, they interact with the bottom transferring part of their momentum to the sediment and to the (bottom) wave boundary layer where turbulence may appear and kinetic energy is dissipated. In turn, the dissipation of energy affects the wave properties and ultimately causes the attenuation of wave amplitude. The capability to predict the processes occurring in the wave boundary layer, such as the transport of sediment, nutrients, pollutants (microplastics, PAH, PCB, PFAS) and micro-organisms (harmful algae, pathogens), is necessary to preserve the ecological and morphodynamic equilibrium of coastal environments.

Scope. The project focuses on the interaction between the seabed and free-surface non-breaking gravity waves propagating over a horizontal sandy bed. Conditions leading to the formation of sand ripples and the appearance of turbulence at the bottom are considered.

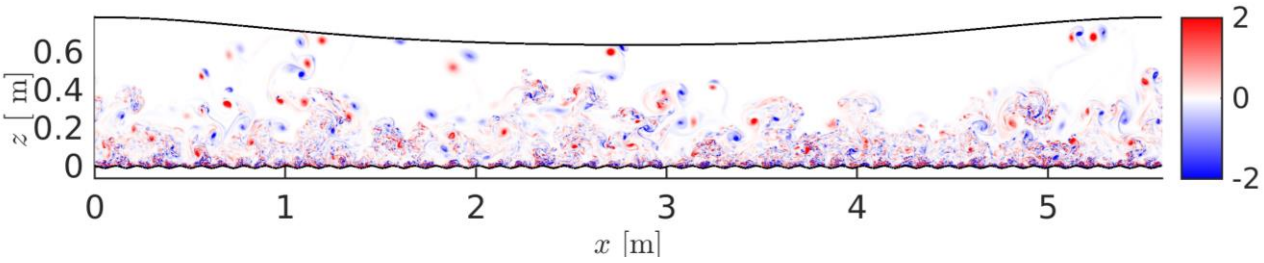
Approach and plan. The investigation will be carried out by means of direct numerical simulation (DNS) of the free-surface flow over movable bed (Eulerian approach) which allows us simultaneously to compute the evolution of the bottom (sediment-fluid interface) and free (fluid-air interface) surfaces. Preliminary results obtained considering a fixed wavy bottom, revealed a wave flow populated by rich varieties of vortices (cf. figure below). The evolution of bedforms considering the fully-coupled system will be investigated for the first time by DNS.

The candidate will further develop the current flow solver by including the solver for the sediment dynamics (two-phase flow), which allows to compute the evolution of the bottom surface. Then, the DNSs and the data analysis will be carried out using HPC facilities.

Requirements. The candidate should have very good skills of numerical analysis and fluid mechanics and good programming experience (fortran, C, C++). Though not mandatory, any experience of parallel programming and computing are particularly appreciated.

Referent: Marco Mazzuoli (marco.mazzuoli@unige.it)

Figure: Dimensionless spanwise vorticity computed from a DNS of non-breaking waves over a fixed wavy bottom: a thick turbulent wave boundary layer is generated close to the bottom while large two-dimensional vortices reach the free surface.



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

***Thematic*: Hydrodynamics and Morphodynamics of Rivers, Coasts, Estuaries and Lagoons**

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.

Referent: Giovanni Besio (giovanni.besio@unige.it)

Relevant links: meteocean.science

Link to the list of projects

Projects in Hydrology and Water Resources Management

Project: Improvements in the accuracy of atmospheric precipitation measurement using disdrometers

Project: Short-duration rainfall event in actual and future climate scenarios

Project: The impact of urban stormwater discharges from traditional to emerging contaminants

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***Thematic*: Hydrology and Water Resources Management**

Project: Improvements in the accuracy of atmospheric precipitation measurement using disdrometers

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

Brief Description:

Accurate and reliable precipitation measurements play a key role in a wide range of applications like flash-flood forecasting, water resources management, and climate change projections and mitigation policies. However, in-situ measurements of liquid precipitation have experienced little conceptual innovation for many decades now. Although prone to instrumental and environmental biases, rain gauge measurements are the most trusted forcing variables of hydrological models. Precipitation measurement biases of catching and non-catching gauges were investigated in previous projects through numerical simulation and wind tunnel tests, showing that their assessment and correction require detailed knowledge of the rainfall microphysical characteristics, typically expressed through the drop size distribution (DSD).

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 analyzed to compare adjusted to reference precipitation, thus validating the DCM with observed time series of rainfall and wind at various aggregation scales.

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.

Referents: Arianna Cauteruccio (arianna.cauteruccio@edu.unige.it), Luca G. Lanza (luca.lanza@unige.it)

Link to the list of projects

***Thematic*: Hydrology and Water Resources Management**

Project: Short-duration rainfall event in actual and future climate scenarios

Keywords: sub-hourly extreme rainfall, IDF curves, climate change impact

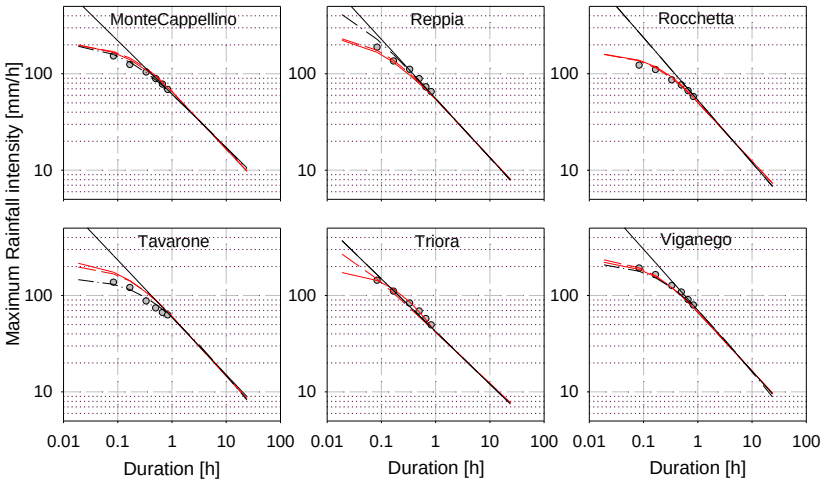
Brief Description:
The characterization of high intensity and short-duration rainfall events is crucial in small-catchment the field of hydrology and in urban hydrology. However short-duration rainfall data are rarely available and generally the length of the sub-hourly data series is significantly lower with respect to the long-duration ones. The aim of the present research is to investigate the transition in the scaling regime of rainfall from sub-daily to sub-hourly timescales in order to improve the capability of the Intensity Duration Frequency curves to provide reliable estimate of the short-duration design storm depth.

Furthermore, in the framework of a climate adaptation approach the estimates of extreme rainfall intensities from sub-daily to sub-hourly timescales in future climate scenarios are needed to tackle the design of resilient urban drainage systems.

Finally explore options for combining gauge, radar data into gridded sub-daily products to add to existing merged products as a key resource for the climate modelling community to validate model outputs.

Referents: Ilaria Gnecco (ilaria.gnecco@unige.it), Anna Palla (anna.palla@unige.it)

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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***Thematic*: Hydrology and Water Resources Management**

Project: The impact of urban stormwater discharges from traditional to emerging contaminants

Keywords: stormwater pollution, stormwater characterization, environmental impact

Brief Description:

Rapid increase in global urbanization is producing multiple environmental challenges, one being the impacts of urban stormwater runoff in terms of quantity and quality issues. On the other hand demands on global water supplies are increasing due to several water stressors, consequently urban water authorities are exploring alternative water sources to meet ever-increasing demands and stormwater represents one of the alternatives. The aim of the research is to improve the understanding stormwater quality to quantifying the environmental and ecological impacts, and treatability, of stormwater.

Among the different pollutants associated with stormwater runoff, microplastics have become a major emerging class of pollutants representing significant eco-toxicological risks for ecosystems and marine environments. However, the investigation of microplastic in stormwater runoff is still an open issue (including the methodology for identification and quantification of microplastics). Therefore, widespread in-depth studies are urgently needed to bridge the knowledge gaps to enable a more comprehensive risk assessment of microplastics in inland waters and support the relevant authorities in developing a policy addressing this issue. In particular, this research aims at investigating the role of stormwater control measure with respect to microplastics thus evaluating the source pathway as well as the potential mobility downstream and therefore the long-term fate.

Re Referents: Ilaria Gnecco (ilaria.gnecco@unige.it), Anna Palla (anna.palla@unige.it)

Link to the list of projects

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

Projects in Biological Fluid Dynamics

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

Project: Water transport processes across the corneal endothelium and corneal homeostasis

Project: Mathematical model of ocular vein pulsation

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***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.

Referent: Jan Pralits (jan.pralits@unige.it)

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

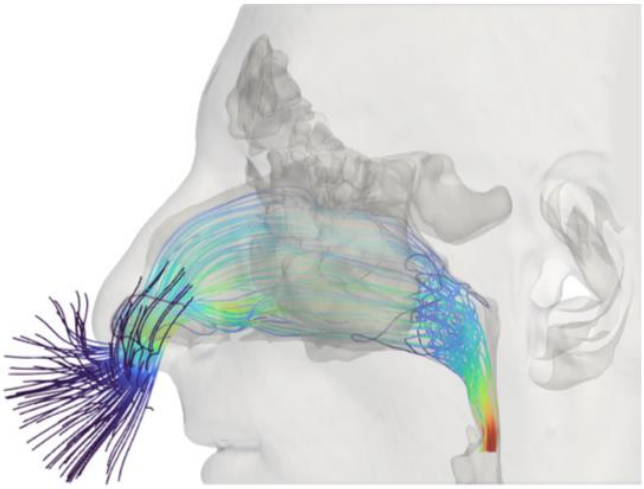

Figure: Streamlines showing the flow during inhaling. Colors show magnitude of velocity; blue is low velocity and red is high velocity.

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***Thematic*: Biological Fluid Dynamics**

Project: Water transport processes across the corneal endothelium and corneal homeostasis

Keywords: Water transport across cell layers, tissue homeostasis, corneal metabolism

Brief Description:
The cornea is a multi-layered tissue (see figure below). The central layer, the thick stroma, has structural functions; the innermost layer, the endothelium, in direct contact with the aqueous humour, regulates the hydration of the cornea by controlling water exchanges with the aqueous. Various vision threatening conditions that may affect the anterior segment of the eye are related to the defective mechanical behaviour of the stroma (e.g., keratoconus) or to impairment of water fluxes across the epithelium (e.g., corneal oedema). Given the importance of the cornea for vision, various mathematical and numerical models of corneal tissue have been proposed, tackling either the mechanical or the hydration aspects. However, a comprehensive study of the biomechanics of corneal tissue in relation to state of hydration and metabolism is missing.

We propose to formulate a model of water transport across the corneal endothelium, aimed at understanding the processes that governs corneal hydration state. The model will account for ion fluxes across the cell layer and corneal metabolism. The model will help us identifying the key parameters that govern corneal homeostasis, which can be possibly be targeted by specific drugs.

Referent: Rodolfo Repetto (rodolfo.repetto@unige.it)

Relevant links: https://www.sciencedirect.com/science/article/abs/pii/B9780323857406000029

Link to the list of projects

***Thematic*: Biological Fluid Dynamics**

Project: Mathematical model of ocular vein pulsation

Keywords: retinal vein pulsation, blood flow, mathematical modelling

Brief Description:
Monitoring Intracranial Pressure (ICP) is essential for detecting various craniocerebral diseases, as well as during clinical care of life-threatening brain insults. While invasive techniques are quantitative and accurate, they can lead to serious complications. Thus, non-invasive ICP monitoring methods are receiving much attention. ICP and other variables describing processes that take place in the brain have manifestations in the eyes; in this respect eyes can be thought of as windows to the brain.

This project focuses on the retinal blood circulation and in particular on retinal veins that, being acted on externally by the intraocular pressure (IOP) can collapse during certain phases of the cardiac cycle. This is an intriguing phenomenon, since elsewhere in the human body pulsation of vessels is much more pronounced in arteries than in veins. The classical explanation is that IOP and ICP pulsations due to the heart beat generate negative transmural pressures in retinal veins.

Objective of this project is to develop an integrated mathematical model of cerebral and ocular blood flow, in which the two organs are coupled in a physiologically accurate manner. Final aim is to link the occurrence of retinal veins pulsation with IOP and ICP, thus enabling indirect estimates of ICP.

Referent: Rodolfo Repetto (rodolfo.repetto@unige.it)

Link to the list of projects

Projects in Geomatics

Project: Precipitable Water Vapor estimation from GNSS onboard a ship

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***Thematic*: Projects in Geomatics**

Project: Precipitable Water Vapor estimation from GNSS onboard a ship

Keywords: Global Navigation Satellite System (GNSS), Zenith Total Delay (ZTD), Precipitable Water Vapor (PWV), atmospheric remote-sensing, Amerigo Vespucci ship

Brief Description:
The use of Global Navigation Satellite System (GNSS) receivers for atmospheric monitoring at detailed temporal and spatial scales, namely GNSS Meteorology, integrated with the environmental parameters observations is a well-established technique capable to remote sense the content of Precipitable Water Vapor (PWV). The technique uses the estimates of the tropospheric Zenith Total Delay (ZTD) coming from GNSS stations, combining this parameter with pressure and temperature observations to obtain the PWV content. The estimation of ZTD and the resulting evaluation of PWV is considered a standard for GNSS static stations, but it is still challenging for kinematic GNSS stations. In this context, limited experiences are found in scientific literature regarding the monitoring of atmospheric water vapor by GNSS in the open sea, typically for short distances or for limited time periods. Therefore, Nave Amerigo Vespucci world tour constitutes an unmissable opportunity to conduct research on PWV monitoring along its track during the entire campaign on the sea (July 2023 – February 2025). The Geomatics Laboratory of DICCA (Genoa University) has installed a GNSS receiver joint with a meteorological station onbord of School Ship Vespucci, thanks to the Sea Study Centre of the Genoa University, Hydrographic Institute and Italian Navy.
The overall objective of the scientific project is to optimize the ZTD estimation joint to the kinematic position in an area as wide as the ocean to create a DataBase (DB) of ZTD and PWV estimations during navigation. The challenging aspects of the proposed project concern the severe weather conditions (like the Cape Horn passage) to which the instrumentation is exposed, the presence of yards and sails, which can interfere with the optimal reception of the GNSS signal, connected to the vessel's attitude due to the sea conditions, to evaluate ZTD and PWV with adequate accuracy and reliability. The project may prove to be an important starting point for the study of the contribution that, tracking the PWV values on the ocean, can provide to the meteorological models.

Referent: Domenico Sguerso (domenico.sguerso@unige.it)

Relevant links: https://earth-planets-space.springeropen.com/articles/10.1186/s40623-017-0740-1

https://www.mdpi.com/1424-8220/20/15/4261

Figure:

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Other Projects

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