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TECNOLOGIA DO AMBIENTE E DO MAR
TÉCNICO LISBOA

Experimental responses and numerical simulations of a hydrodynamic transparent floating body

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Outline

Experimental responses and numerical simulations of a hydrodynamic transparent floating body:

1. Background;
2. Objectives
3. Experimental campaign;
4. Numerical simulations (forecast);
5. Numerical simulations (hindcast);
6. Conclusions;
7. Future work

1. Background

- **MSc in Mechanical Engineering at IST (1997):**
  - Lagrangean model to predict the behavior of oil-spills at sea, as a module for MOHID large circulation model;

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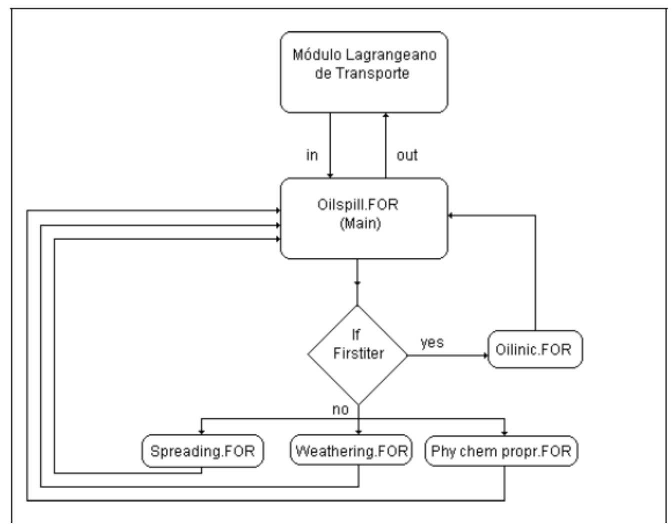
Modelação Numérica de Derrames de Hidrocarbonetos no Mar: Aproximação Lagrangeana do Transporte

Sérgio Bruno N. RIBEIRO E SILVA
(Licenciado)



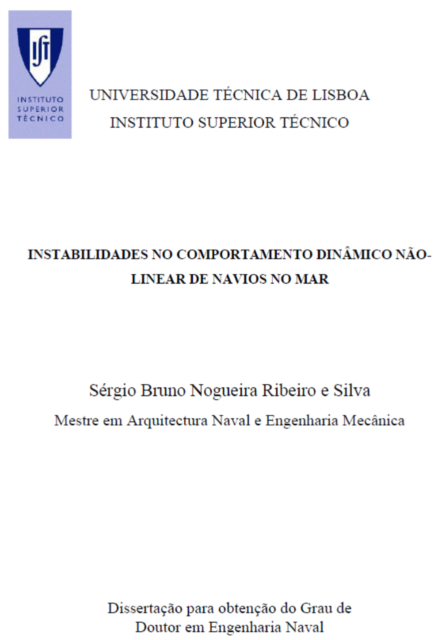
1. Background

R&D Project: **ASTRIIS** (Atlantic Sustainability Through remote and In-situ Integrated Solutions), where a large group of partners (Tekever Space, CoLAB +ATLANTIC, CEiiA - Centro de Engenharia e Desenvolvimento, IST, Abyssal S.A., Hidromod, Spinworks, ISQ, WavEC, Universidade do Algarve, Universidade do Minho, Faculdade de Engenharia do Universidade do Porto, Oceanscan) aims to develop an Autonomous Surface Vehicle for Search and Rescue (SaR) along with a scalable tool for simulation and training of SaR operations (with a sustainable business model) using an high-fidelity immersive virtual marine environment;

Scientific Paper Presented: S. Ribeiro e Silva, L. Eça: **CFD Simulations of a Drowning Body at Sea**, ASME 42nd International Conference on Ocean, Offshore & Arctic Engineering (OMAE2023 Paper# 105014).

1. Background

- **PhD Studies Programme in Naval Engineering at IST (2008)**:
  - Experimental and numerical applied research of the hydrodynamics of different floating structures;
  - Development of several codes to predict performance of unstabilised and roll stabilization systems, including anti-rolling U-tanks.



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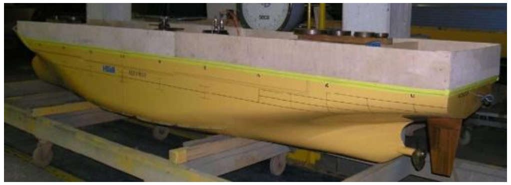
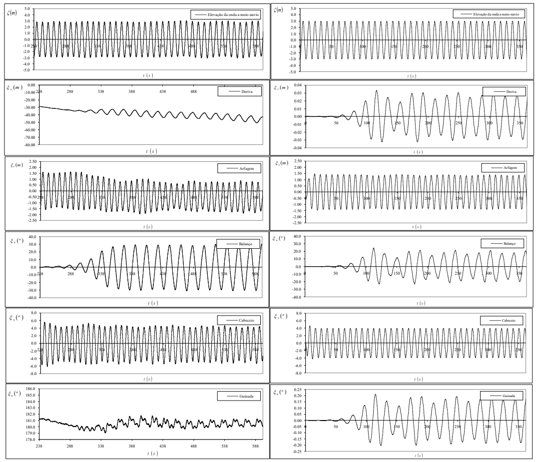
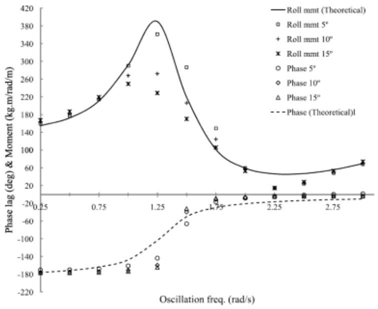
INSTABILIDADES NO COMPORTAMENTO DINÂMICO NÃO-LINEAR DE NAVIOS NO MAR

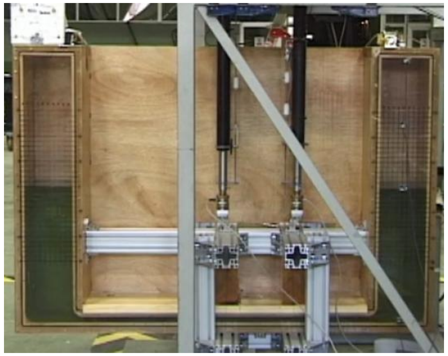
Sérgio Bruno Nogueira Ribeiro e Silva
Mestre em Arquitectura Naval e Engenharia Mecânica

Dissertação para obtenção do Grau de Doutor em Engenharia Naval



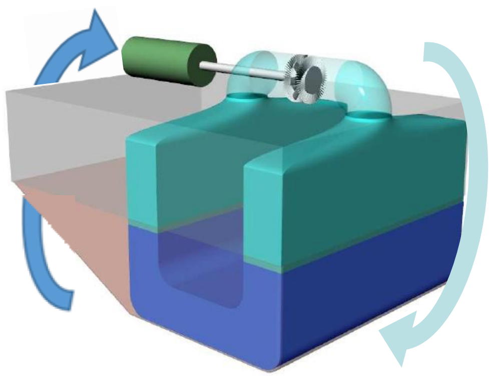


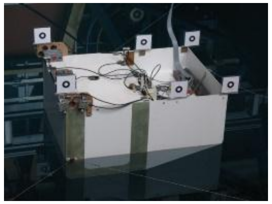


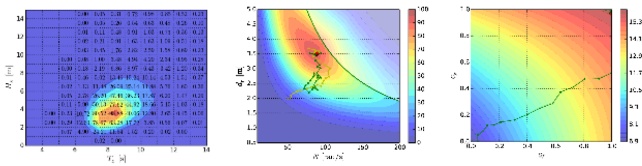


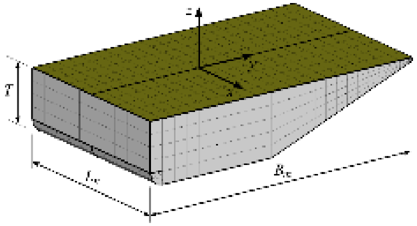
1. Background

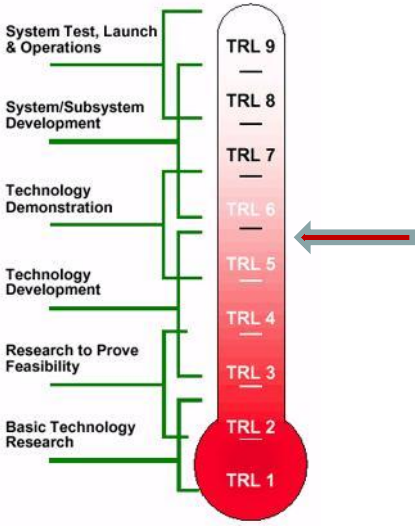
- **UGen Concept Development and Patent Registration.**
  - Development of the Wave Energy Converter prototype “UGen”, whose patent registry was accepted in 2010.



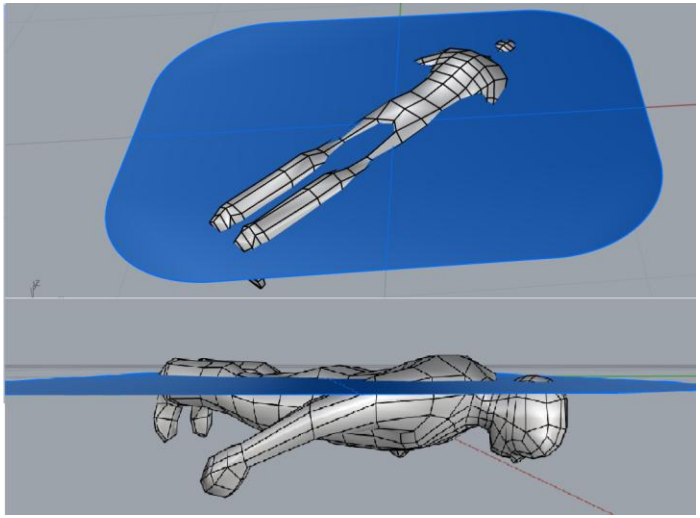








2. Objectives



Motivation to conduct this study arose from the fact that despite Computational Fluid Dynamics (CFD) tools are nowadays justifiable for hydrodynamic studies, most Search and Rescue (SaR) and Hazardous Material (HazMat) operational models still utilise algorithms of the wind and wave component of drift of the objects of interest which solely rely on empirical data available (see e.g., Breivik & Allen 2008 or Ribeiro e Silva, 1997).

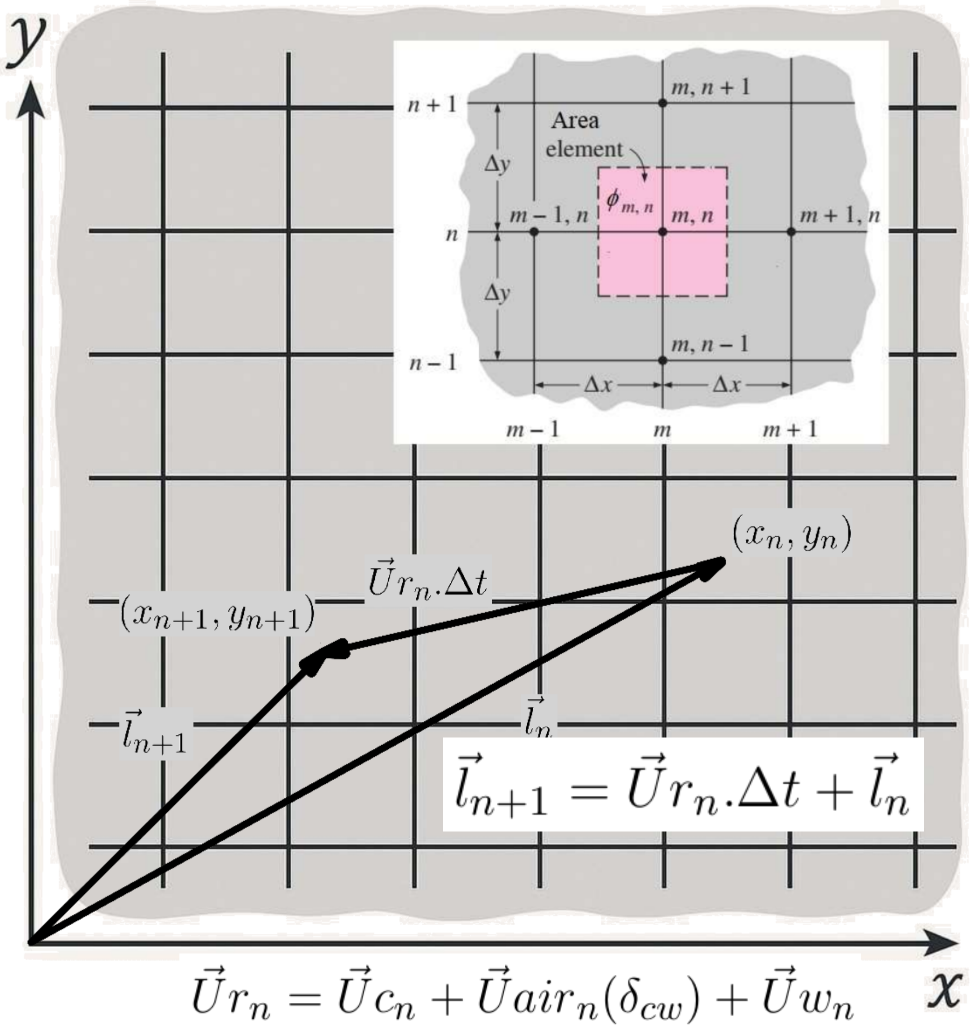
Hence, this **numerical model** addresses the **6 DoF motions** along with **drift displacements** of hydrodynamic transparent floating bodies under the action of real-world meteocean (meteorological and oceanographic) conditions, i.e., waves, wind and currents at sea.

The **case study analysed with field experiments** correspond to a drowning body, whose dimensions are practically negligible in comparison with the dimensions of the incoming waves, but whose viscous forces are significantly large in comparison with inertial forces.

2. Objectives

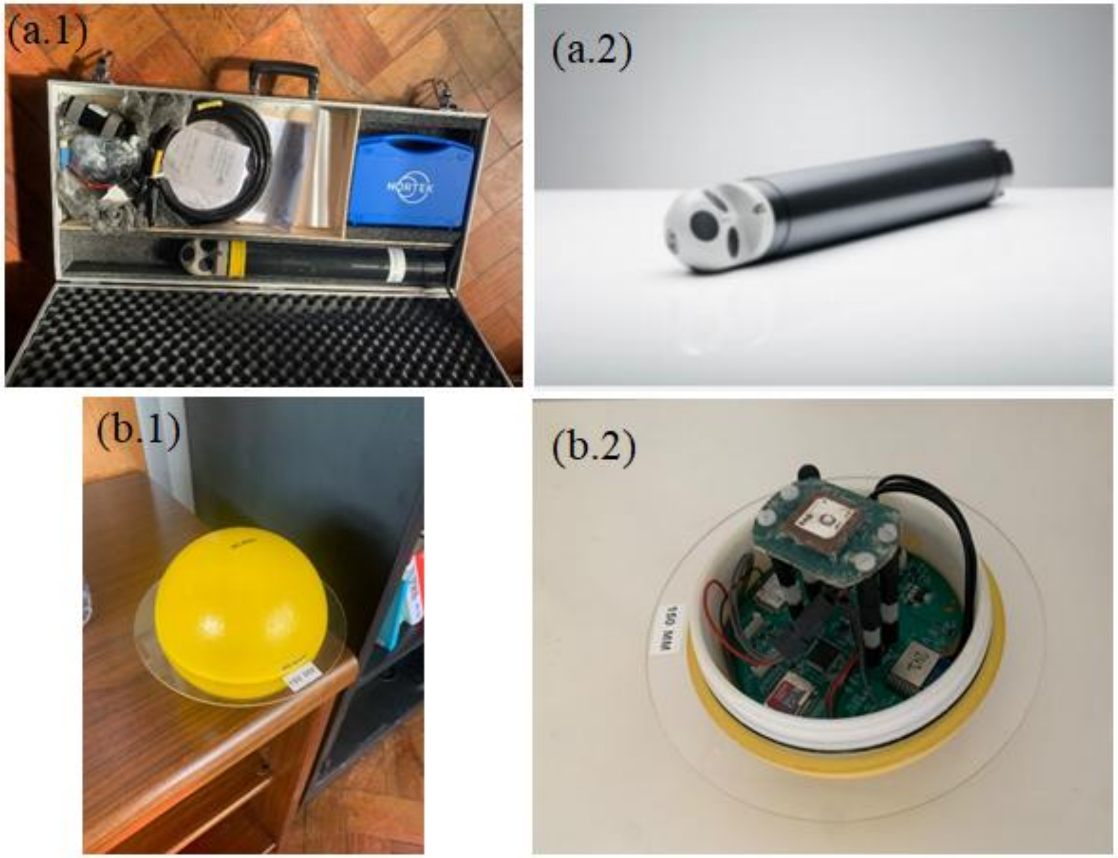
Dynamic and hydrodynamic effects in waves for a given frequency may be included in the 6 DoF responses calculations, which are based on the potential flow BEM method (WAMIT, 2004).

While the **drift displacements** of the floating body **are derived from a Lagrangean drifter model** providing the current at the sea surface (higher order wave's Stokes drift effect) at a given point of a large grid, and therefore having a much larger time step. In this particular case, current information at the sea surface has been extracted from a sophisticated hydrodynamic large circulation model **MOHID** (Neves,1985).



3. Experimental campaign

3.1 Preparation activities for the MoB exercise

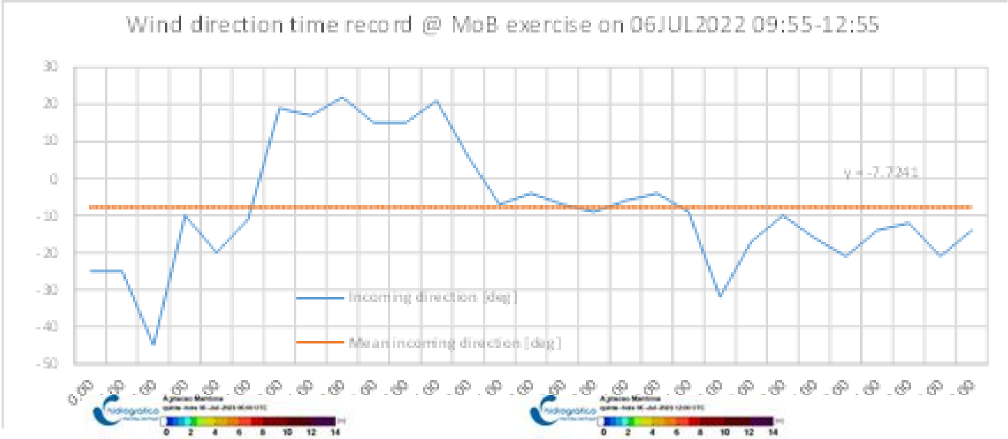


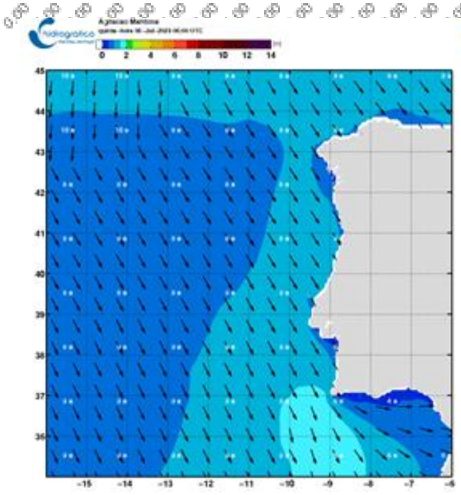
3. Experimental campaign

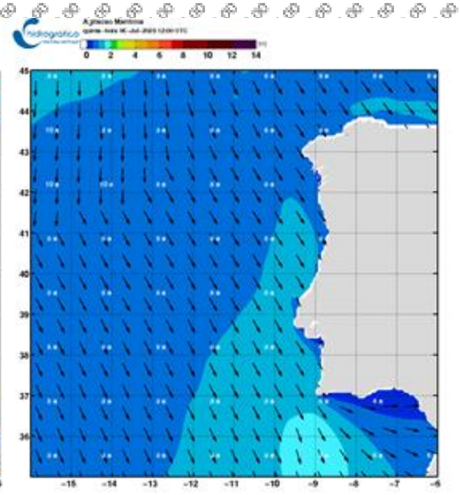
3.2 Conduction of the MoB Exercise in Peniche

3. Experimental campaign

3.3 Meteocean conditions: measured wind and predicted waves

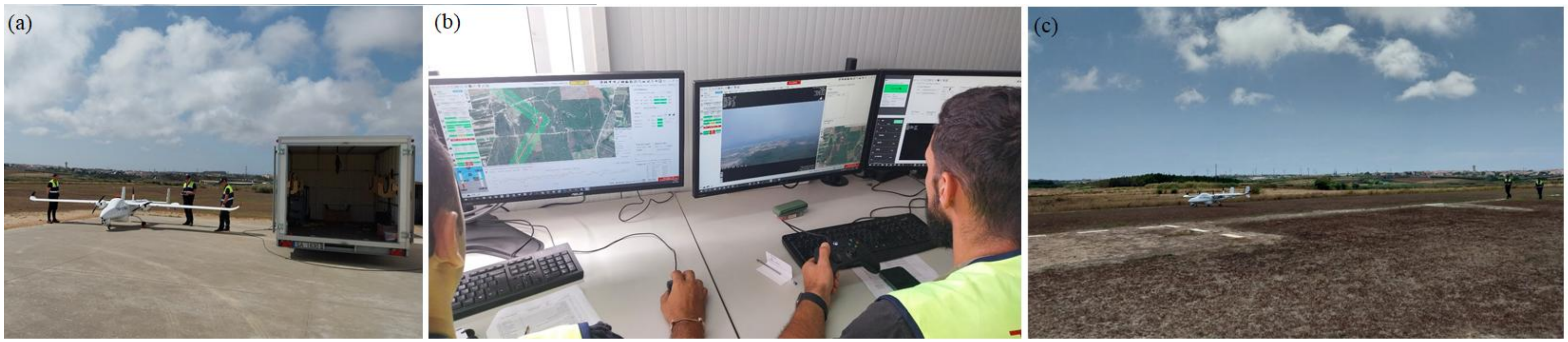


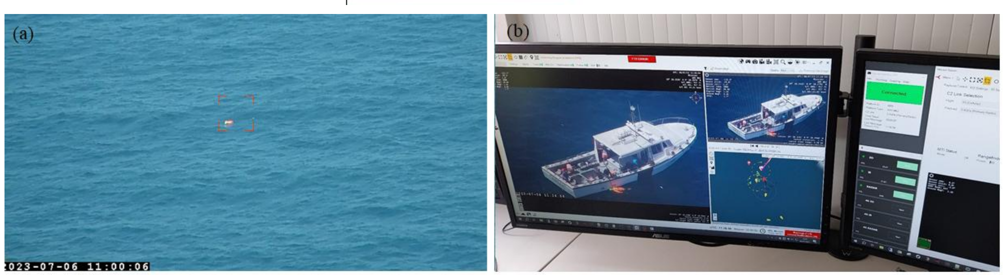




3. Experimental campaign

3.4 Manikin launch, detection and recovery

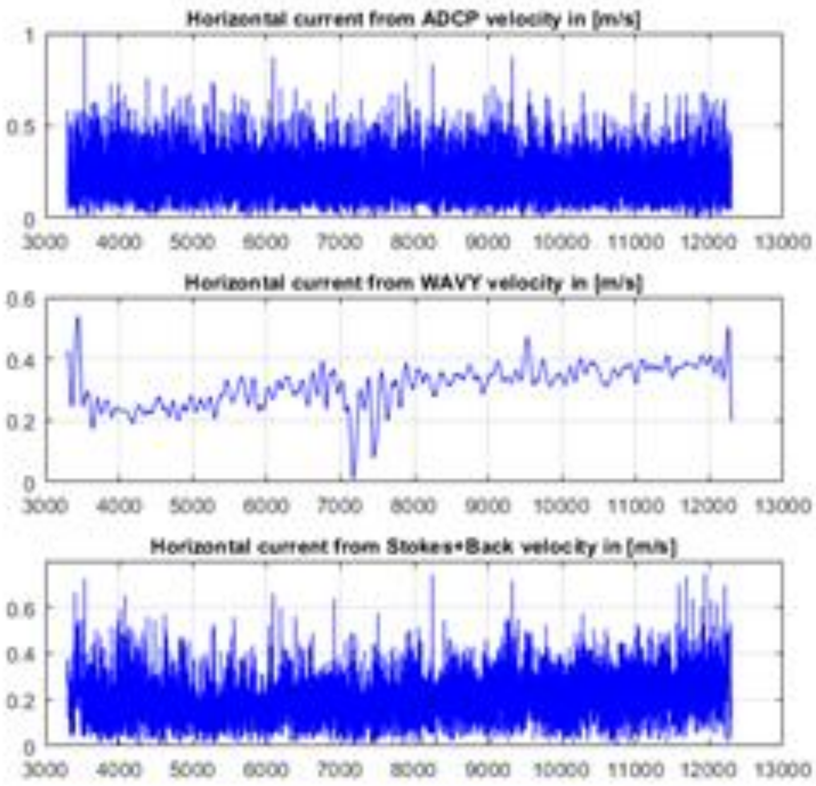




3.5 Post-processing of experimental data measured during the MoB exercise – Swell from WAVY

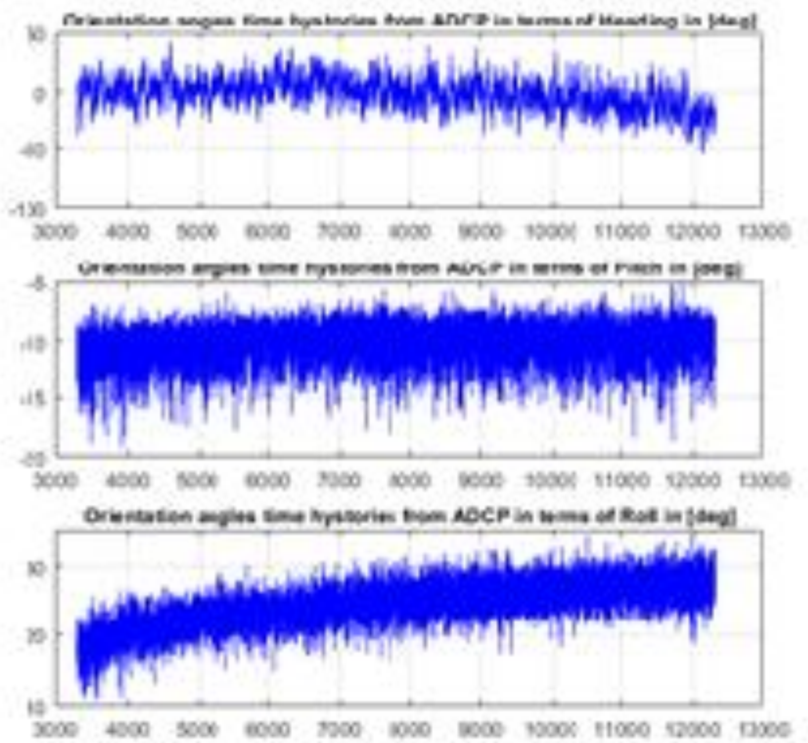
3. Experimental campaign

3.5 Post-processing of experimental data measured during the MoB exercise – Surface current from ADCP, WAVY and Stokes + body drift



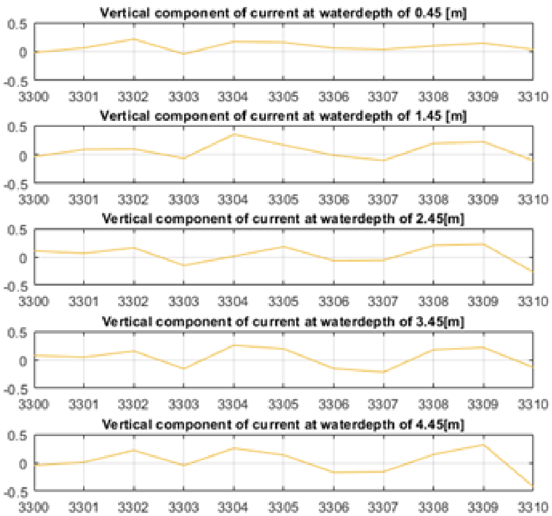
3. Experimental campaign

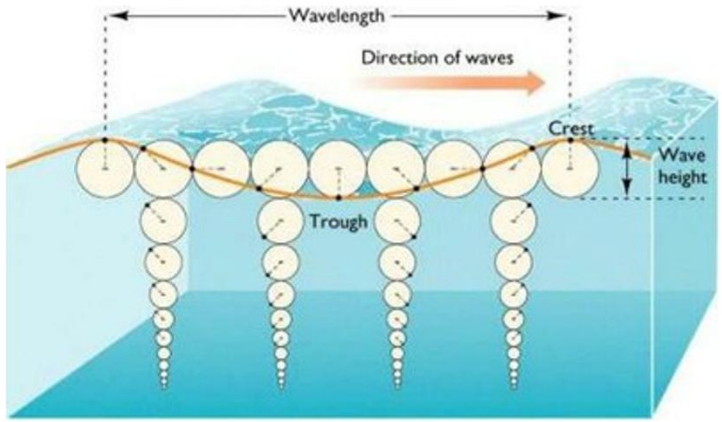
3.5 Post-processing of experimental data measured during the MoB exercise – Bow, roll and pitch of the manikin´s leg



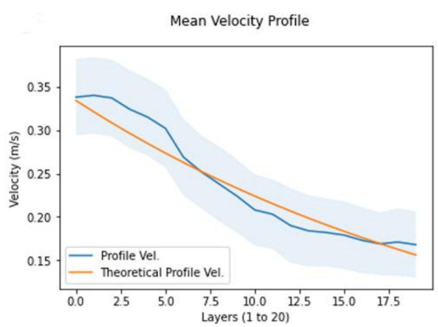
3. Experimental campaign

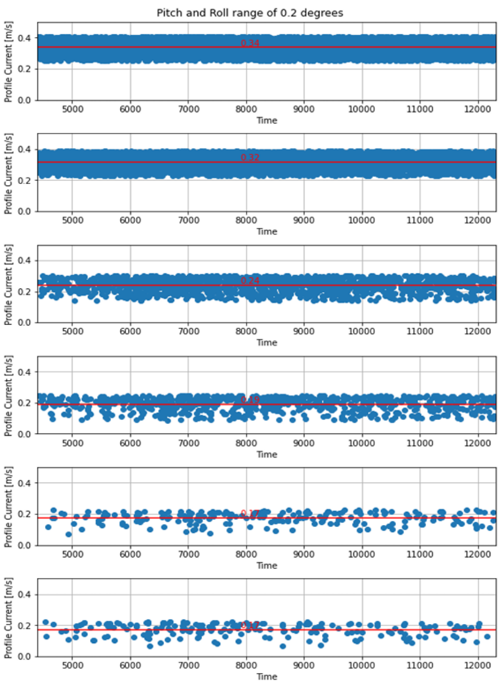
3.5 Post-processing of experimental data measured during the MoB exercise – ADCP's vertical profile of the current





$$U^2 = u^2 + w^2 = (H_s/2)^2\omega^2 e^{2kz} = (\zeta_a)^2 gke^{-2kd}$$





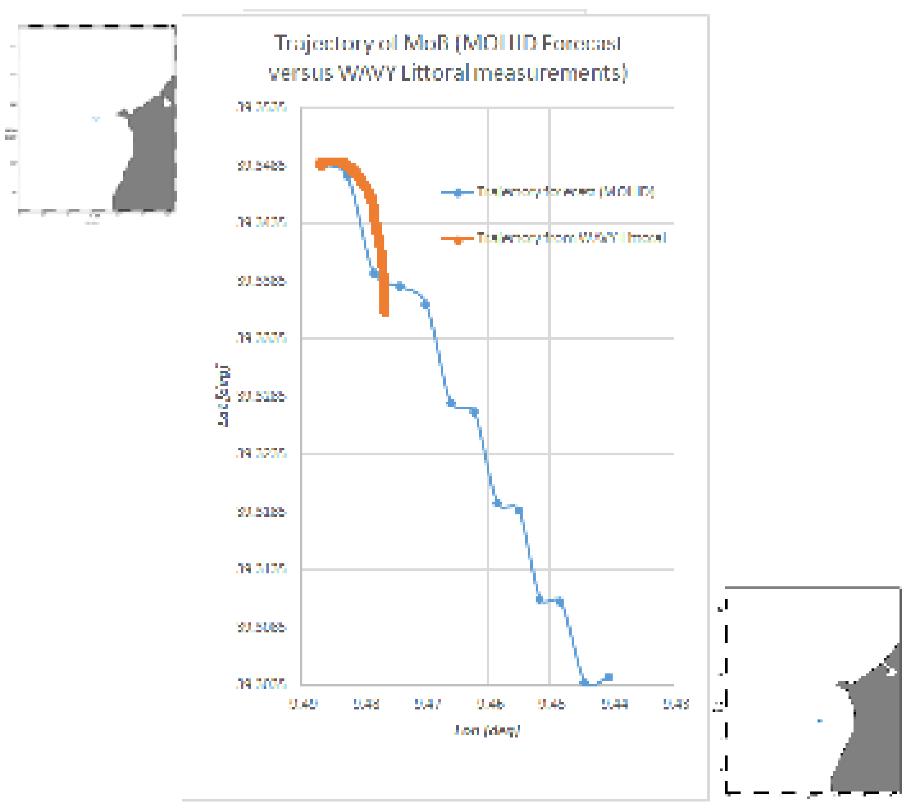
4. Numerical simulations (forecast)

This figure compares and contrasts the manikin **predicted trajectory against the track measured by the WAVY littoral**;

Major source of uncertainty of a numerical simulation lies in the wind and current data, modelled or observed, since the fields will always contain errors. Plus two types of fluctuations or errors:

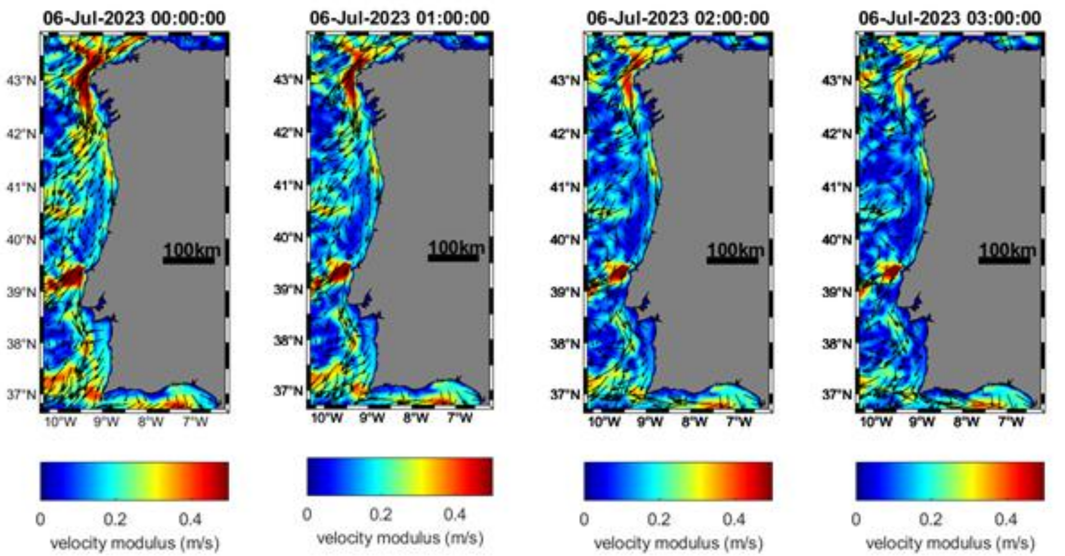
- The **sub-grid scale fluctuations** in numerical modelling.

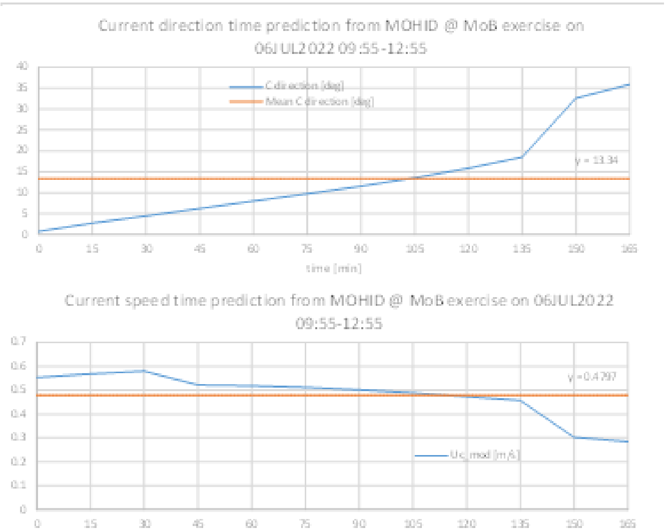
- The temporal and spatial observation **error of representativeness**.



4. Numerical simulations (forecast)

4.1 Current - As it can be seen in these figures (LHS Eulerian field and RHS Lagrangean record), the MOHID hydrodynamic model predicted that the current would have a practically constant N direction (13.3º) and an average speed of 0.48 [m/s] (with maximum and minimum current values of 0.58 and 0.28 [m/s]).





4. Numerical simulations (forecast)

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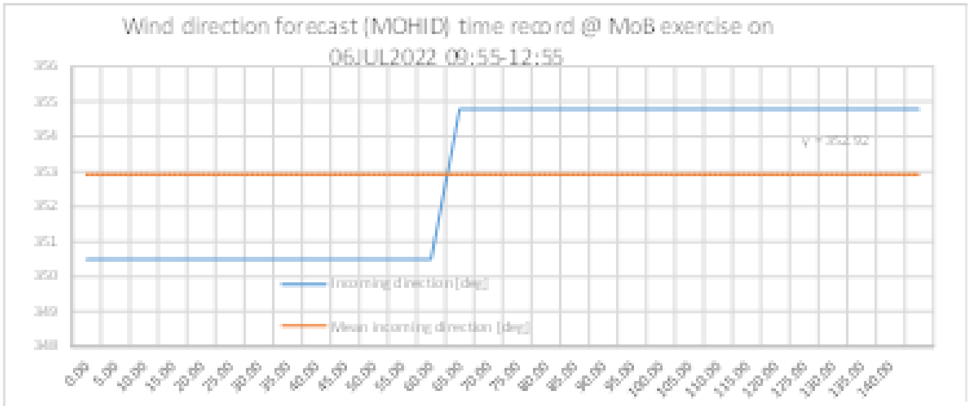
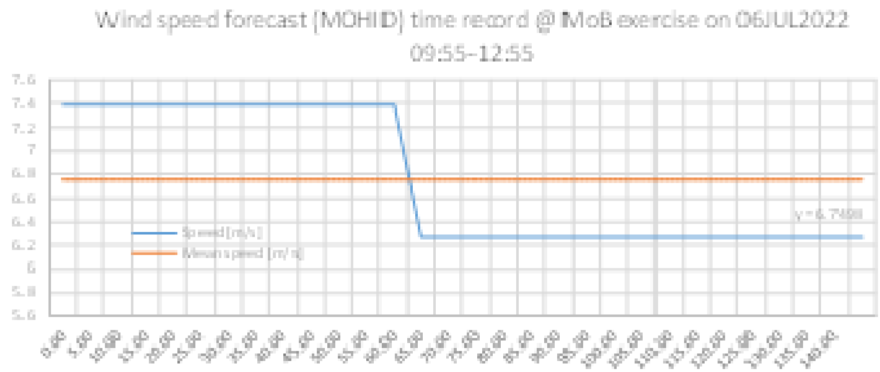
4.2 Wind - Regarding the wind, as can be seen in this figure, the speed predicted by the MOHID hydrodynamic model had a practically constant direction of N (353º) and an average value of 6.7 [m/s].





4. Numerical simulations (forecast)

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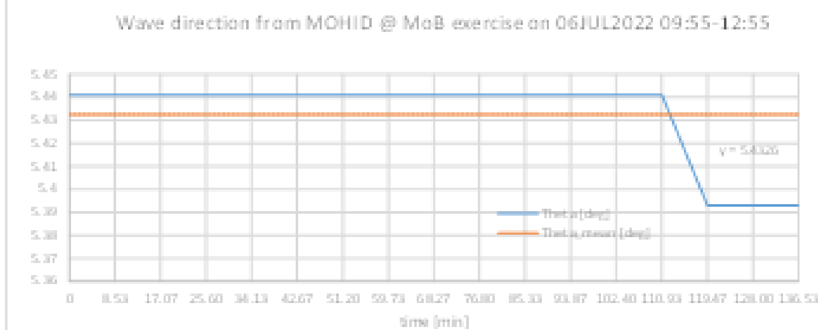
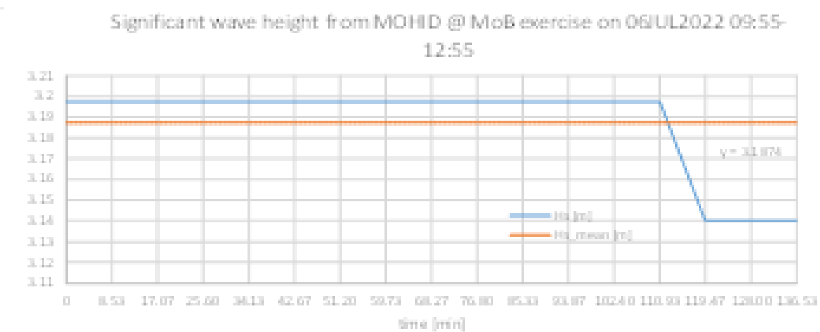
4.3 Waves - Regarding the swell, as can be observed in this figure, the maritime agitation predicted by the MOHID hydrodynamic model for the day July 6, 2023, had a practically constant direction of N (5.4º) and a significant wave height of 3.2 [m], a value considered very high for this time of the year (Summer), which fortunately (to avoid difficult-to-interpret and model non-linear phenomena) did not occur..





5. Numerical simulations (hindcast)

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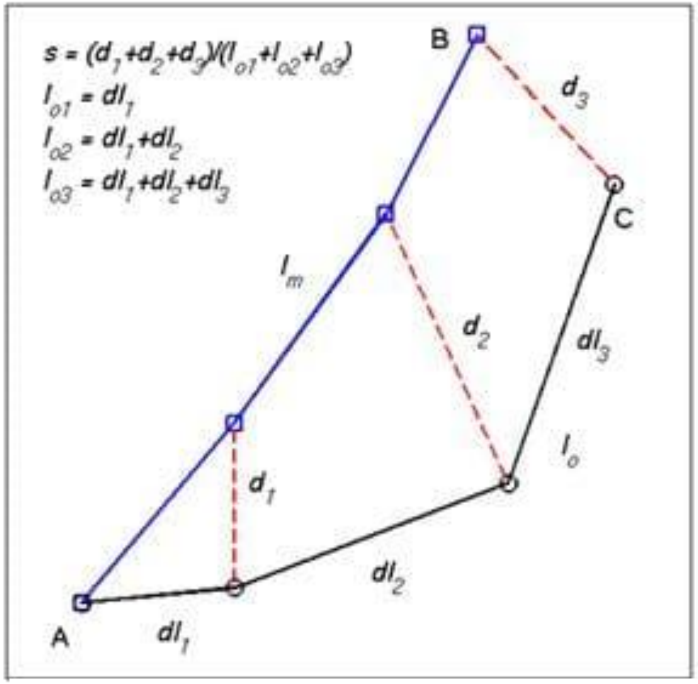
- The **Lagrangean separation distance** (d) between the endpoints of simulated and observed drifter trajectories is often used to assess the performance of numerical particle trajectory models. However, d **fails to indicate relative model performance** in weak and strong current regions, or to reveal its **performance under different formulations**. Hence, the resulting simulatec tracks were evaluated using the **Skill Score** (SS), which evaluates the separation between the manikin/drifter and the numerical model trajectories along their entire path, normalized by the total length of the path (L) given by Eqns.:

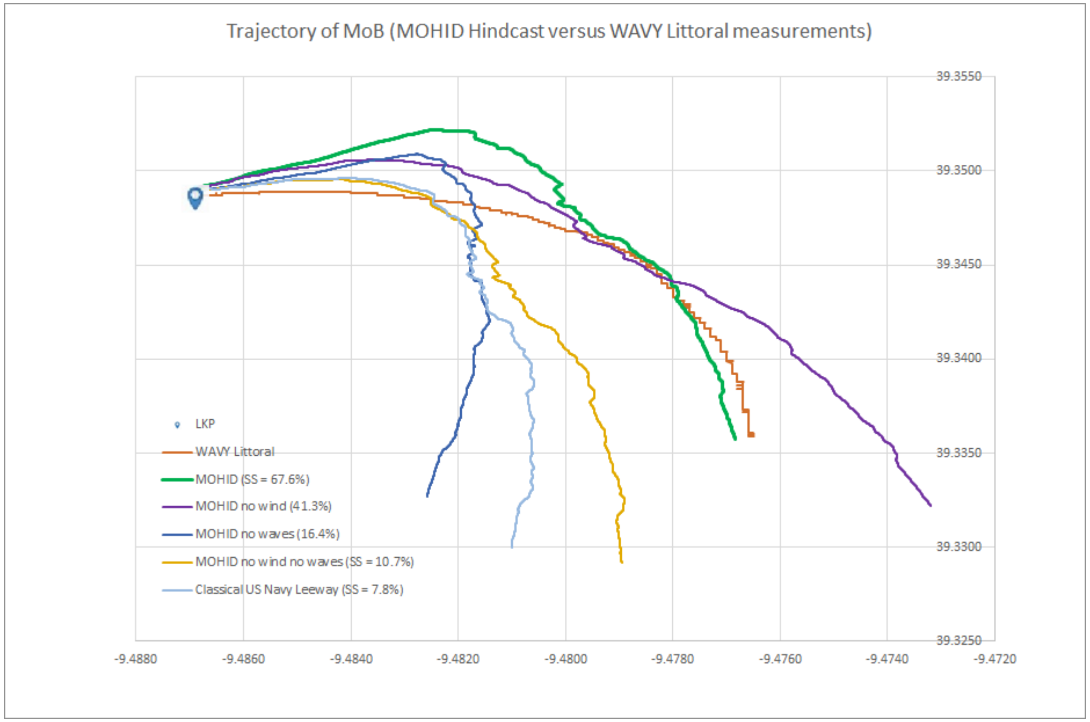


$$SS = \begin{cases} 1 - \frac{s}{tt} & \text{if } s <= tt \\ 0 & \text{if } s > tt \end{cases}$$

$$s = \frac{\sum_{n=1}^{N} d(n)}{L}$$

5. Numerical simulations (hindcast)

- The simulated a posteriori drift trajectory of the manikin (hindcast, with local current measurements from WAVY Littoral, wind from the anemometer, and wave data from WAVY) and the real-life trajectory measured on July 6, 2023, are shown in this Figure, resulting in a negligible difference between the two final positions ($dLat$ = 17.4 [m]; $dLon$ = 25.5 [m]) and a reasonable SS of 0.676.



6. Conclusions

- These numerical results represent a further **improvement into the existing capabilities** like the U.S. Coast Guard's SAROPS, Canadian CANSARP, and French MOTHY that also use various environmental inputs to predict drift trajectories of small floating bodies at sea and may result on creation of an enhanced tool for training and simulation of SaR operations providing a due experimental validation programme will be conducted afterwards.

- Namely, **trajectories of small floating bodies at sea**, such as life rafts and survival craft which often have ballast and various load conditions that affect their immersion ratio and drift behaviour, non-powered vessels, such as small boats without propulsion or shipping containers of larger dimensions, often partially submerged objects and whose drifting is induced by local waves, wind and current vector fields, **should be assessed using a tool similar to SaR@VRS**

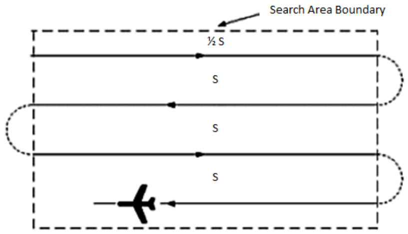
7. Future work

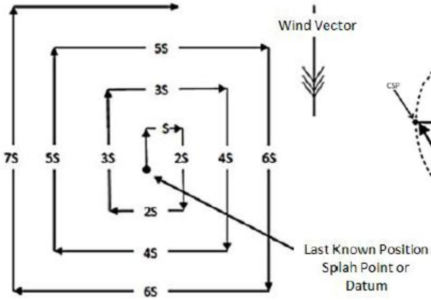
Scientific Papers under Preparation:

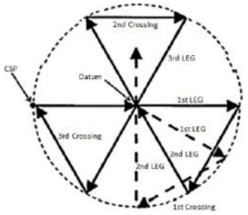
S. Ribeiro e Silva, L. Pinto, D. Lourenço, R. Neves, P. Pinto, A. Relvas: **Numerical Simulations of Responses of Hydrodynamic Transparent Floating Bodies at Sea**, Frontiers.

Funded R&D Proposal under Preparation (the floor is open for discussion):

- Virtual Reality as a day to day tool for testing and training of SaR observers;
- Mature technology for realistic target and sea-surface virtual representations;
- Optimization of SaR operations.







Ribeiro e Silva, S.

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