

VALIDATION OF A NUMERICAL MODEL FOR DISPERSION OF HEAVY MARINE PLASTIC

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INTRODUCTION

Plastic debris poses a significant threat to marine and coastal ecosystems (Figure 1), and its transport behavior is influenced by both environmental factors and plastic characteristics. Most of the current numerical transport models (Eulerian or Lagrangian) ignore the inertial character of the particles and consider them as passive drifters, which is an acceptable simplification to address the study of light particle transport. These transport models have been satisfactorily applied to study the transport of buoyant plastics in open oceans (e.g., Van Sebille et al., 2012), regional areas (e.g., Zambianchi et al., 2014, 2017), and closed water bodies (e.g., Núñez et al., 2019, 2021). However, inertial forces are relevant in the transport processes of heavy particles. Recent studies, such as those by Stocchino et al. (2019), De Leo et al. (2021), and De Leo & Stocchino (2022), have highlighted the significant impact of inertial forces on the transport of negatively buoyant particles, causing an increased settling velocity and altering their overall transport by waves. However, the study of inertial forces in plastic debris is still in need of improvement. The main objective of this study is to validate a new predictive numerical tool that accounts for the inertial effects of plastic debris transported by waves.



Figure 1 - Plastic debris in the marine environment (Suances estuary, Cantabria, Spain, 2023).

MATERIAL AND METHODS

To achieve this goal, a series of numerical experiments are performed using a combination of Computational Fluid Dynamics (CFD) modeling and Lagrangian transport modeling. CFD modeling, specifically IHFOAM (Higuera et al., 2013a, 2013b) based on interFoam of OpenFOAM® (OpenMFG, 2007), is used to simulate regular and irregular wave conditions. The Lagrangian modeling component is based on a modified version of the Maxey-Riley equations (Maxey & Riley, 1983) and includes inertial forces, turbulence effects, and bottom friction of different plastic types (in terms of size, shape, and density) in the drag coefficient, as well as additional Brownian motion. In

addition, the Lagrangian model accounts for the bottom friction, which plays an important role in modeling the transport of heavy plastic debris.

The aim of these numerical experiments is to replicate the laboratory tests conducted by Nuñez et al. (2023), who analyzed the behavior of 15 different types of plastic debris (in terms of size, shape, and density) under two regular wave conditions: W1 ($H_s = 0.18$ m; $T_p = 1.5$ s), W2 ($H_s = 0.10$ m; $T_p = 2.0$ s), and an irregular wave condition: W3 ($H_{m0} = 0.1$ m; $T_p = 1.5$ s; TMA spectrum). Through this approach, a comparison is intended between the results obtained with this numerical tool and those previously published in the referenced research.

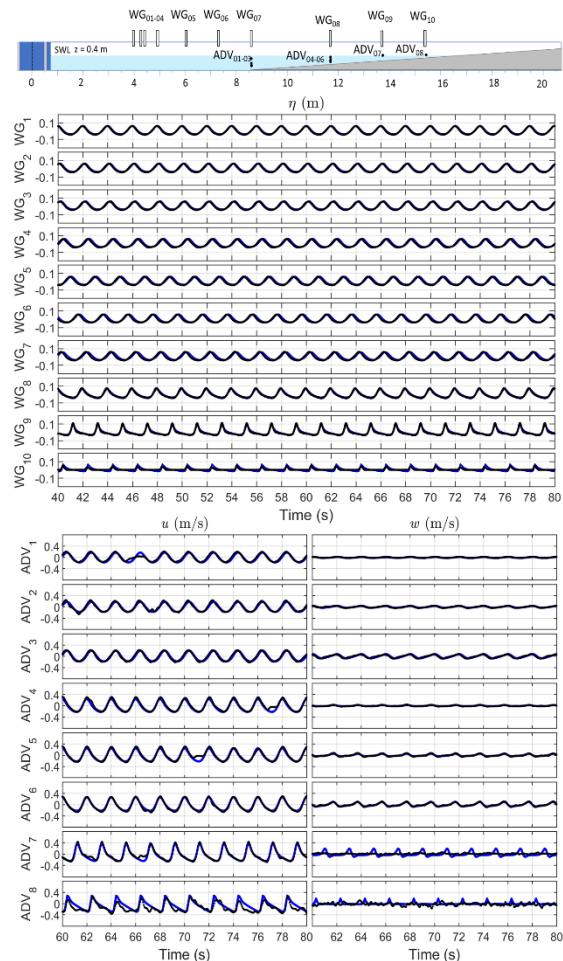


Figure 2 - Comparison of hydrodynamic parameters (water level - η and wave currents - u , w) between numerical results (blue line) and laboratory measurements (black dots) for W2 wave condition.

RESULTS AND DISCUSSION

The preliminary findings demonstrate the successful replication of plastic debris transport and dispersion under the analyzed wave conditions. Figures 2 and 3 show that both the hydrodynamic and plastic-debris transport and dispersion results are in good agreement with those observed in the laboratory. By incorporating inertial forces, turbulence, plastic debris characteristics, and bottom friction, the model offers a comprehensive approach to enhance our understanding of plastic debris transport dynamics, especially for heavy plastics. These factors are critical in modeling such plastic debris.

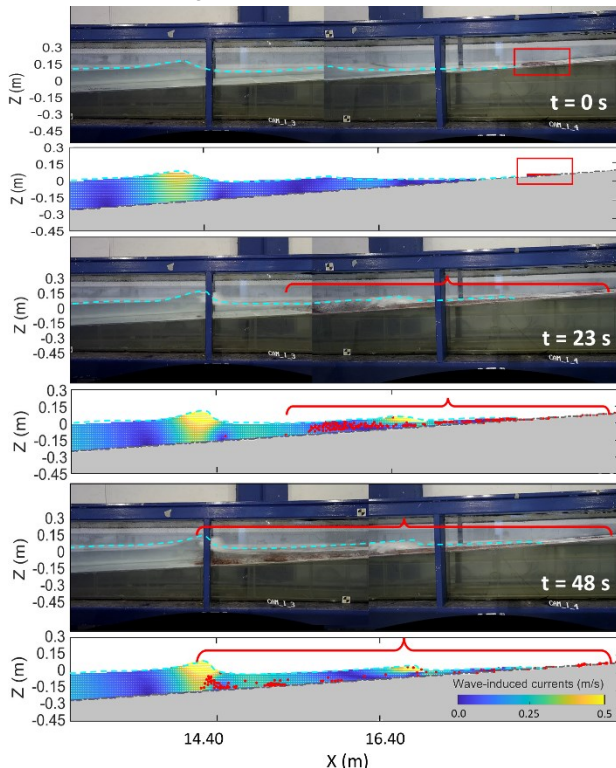


Figure 3 - Preliminary results of dispersion of PVC microplastic debris ($\rho_{PVC} = 1340 \text{ kg/m}^3$; $d_h = 0.002 \text{ m}$) under the W2 wave condition.

In conclusion, this study provides a promising framework for advancing the understanding of plastic debris transport, especially in the context of wave action. The integration of inertial forces into numerical modeling enhances both its accuracy and applicability, particularly in scenarios involving heavy plastic particles. This research significantly contributes to ongoing efforts aimed at addressing the environmental challenges associated with plastic debris in marine ecosystems. A detailed analysis of the numerical results will be shown at the Conference.

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