Unraveling the Fate of Plastic Debris in the Coastal Ocean

Stokes drift: Modern challenges in mathematical theory and applications to marine sustainability

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Background and motivation

I am a mathematician with a **genuine interest in real-world applications**, particularly in the study of **surface water waves and coastal processes**. I have developed mathematical and computational models that describe the propagation of waves in highly nonlinear scenarios, which are crucial in understanding various natural phenomena. As a **SEAS-fellow**, my goal is **to investigate the dispersion of impurities in the coastal ocean**. My research centers on understanding how factors such as density and particle size influence the behavior of impurities in the coastal ocean, with a special emphasis on their interactions with biological processes. I plan to design an experimental campaign aimed at collecting state-of-the-art data. Furthermore, I will incorporate artificial intelligence to enhance data processing, recognition, and predictive modeling. These approaches will introduce **additional dimensions of analysis to my research**, enriching its scope and impact.

Project description

In this project, our goal is to develop dynamic models for predicting the vertical distribution of microplastics within the water column in the coastal ocean. We aim to investigate the Lagrangian transport of various substances in this region, integrating recent advancements in inertial particle motion and considering biological processes like biofouling, along with the influence of infragravity waves. These models have broad applicability, addressing pollutants of different densities and sizes, and can serve as forecast models or as training data for neural networks. Ultimately, our objective is to contribute to the development of more effective waste management and cleanup policies.

Main questions

- How do the density and shape of plastic waste alters the Lagrangian transport of these inertial particles?
- How can we accurately model the transport of particles in the coastal ocean, considering the strong influence of infragravity waves with a broad-banded spectrum that alters particle paths?
- How does biological fouling in microplastics contribute to an explanation/ prediction of vertical distribution of microplastics in the water column?
- How might previous challenges offer insights for the creation of more effective waste management and cleanup policies?"

Aims (and/or milestones)

- **Conduct an Experimental Laboratory Campaign on** Lagrangian transport of particles of varied densities and sizes emulating biological fouling.
- **Establish an Interdisciplinary Team** to collaboratively develop dynamic models for biofouling.
- **Publish Scientific Papers** based on the research findings.
- **Enhance Plastic Motion Forecasting and Waste Management in the coastal ocean**
- **Develop AI Tools** for further advancing the capabilities of research in the coastal ocean.

Marine sustainability

Since the 1950s, **the global production of plastic has outpaced that of almost every other materia**l. In [1] estimated that 79 percent, 6557 million metric tons, of plastic waste the world has ever produced to 2016 was accumulated in landfills or the natural environment. Unlike other materials, **most plastics do not biodegrade** but instead **degrade via interaction with the natural environment** because of physical, chemical, and **biological processes.** Plastic pollutants of various sizes exist in the oceans [2]. In [3] categorized microplastic as less than 1 mm and greater than 0.1 µm. These **microplastics are entering marine ecosystems at an unprecedented level**. One basic problem is understanding **where particles end up**.While our understanding of larger buoyant plastic particles has advanced in recent decades, less than 1% of ocean plastic is found floating on the surface [4]. In contrast, non-buoyant particles follow distinct pathways and have intriguing fates within the water column that remain unresolved, and our current cleanup strategies do not effectively address this challenge.

Highlighted results

- **Research papers and Collaborations:**
  - In preparation: **"Lagrangian Downward acceleration as a diagnostic of wave breaking in shallow water"**. Long abstract submitted for the reputable ICCE-2024. Work in collaboration with researchers from UiB, Norwegian Meteorological Institute and Hemlholtz-Zentrum Hereon.
  - In preparation: **"Buoyant Surface Objects in the Surf Zone: Recognition based on Improved YOLOv5**" in collaboration within some members of the Fluid Mechanics and Statistics group at UiB and ICF-UNAM.
  - In preparation: **"Reflection and transmission of a surface wave in a variable depth domain"** in collaboration with UNAM and Seattle University.
- **Co-Ledearship/Co-Organization:**
  - Co-leading Research group on **Improved Mathematical Methods for Capturing Topography in the Kinematic part of Water Wave Equations in Coastal Domains.**
  - **Co-organizing** an exhibition on 3D Printing, specialized in mathematical objects/models and recently in **custom pieces for experimental campaigns**. Previous exhibition here.
- **Experimental Campaign:** Contributing to the Design of an Experimental Setup for Investigating Lagrangian Transport of Inertial Particles with varied densities and sizes.
- **Outreach Activities:** Participated at SASIP meeting 2023, UiB Career Days 2023, and Your Pathway to Collaborative Projects.

Figure 1: Dron image from The island of Sylt ,Germany. Field Campaign, September 2019. See [5] .

Supervisory team

Supervisor: Professor Guttorm Alendal, a visionary researcher in the Department of Mathematics at UiB, specializes in applying cutting-edge data-driven models to gain practical insights into highly non-linear problems. Guttorm's research focuses on the use of mathematics to address sustainable development issues, acting as a link between local industries and STEM career graduates.

Co-supervisor: Professor Henrik Kalisch, a distinguished researcher in the Department of Mathematics at UiB, is renowned for his thorough and innovative research on the mathematical modeling of nearshore processes. His pioneering and prolific contributions have made him a leading figure in this dynamic field.

References:
[1] Geyer, Jambeck, Law (2017): Production, use, and fate of all plastics ever made. Science advances, vol. 3, e1700782.
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[3] Lambert et al. (2014): Occurrence, degradation, and effect of polymer-based materials in the environment. Rev. Environ. Contam. Toxicol., vol. 227, pp. 1–53.
[4] Sebille (2015): The ocean's accumulating plastic garbage. Physics Today, vol. 68, pp.60-61.
[5] Bjørnestad, Buckley, Kalisch, et al. (2021): Lagrangian measurements of orbital velocities in the surf zone, Geophys. Res. Letters , vol.48, e2021GL095722.