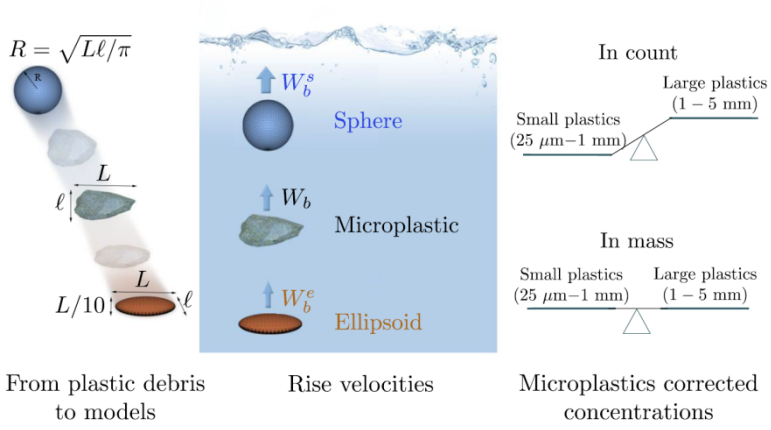
Host institution : IMFT& IMRCP
Supervisor : Matthieu MERCIER (CR, IMFT)
Co-supervisor : Alexandra TER HALLE (CR, IMRCP)
Funding : Doctoral fellowship provided by the Doctoral school (SDUE2)

Study of the vertical distribution of plastic particles : Modelling, characterization and comparison with observations

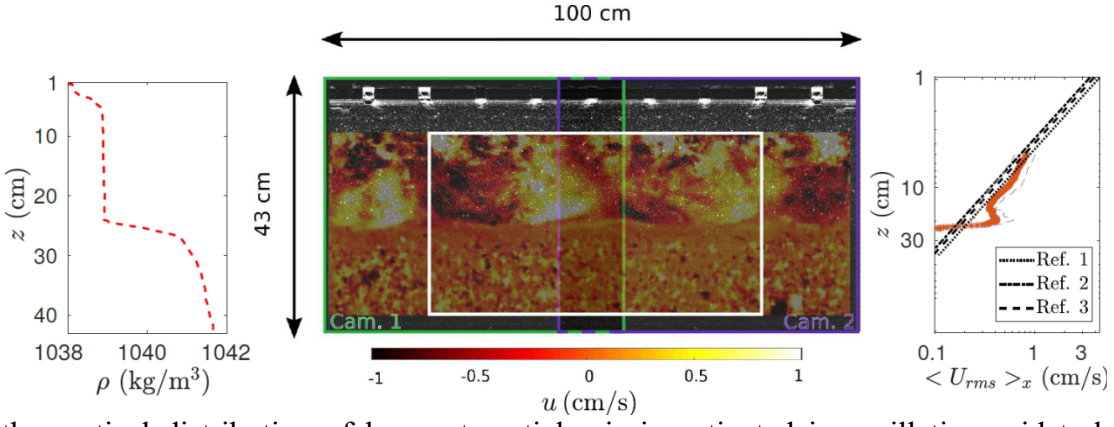
The annual plastic input in the ocean is estimated to be 200 000 tons, but to the best of current knowledge, only 1 % of this quantity is retrieved. Where could the rest be ? For logistical reasons, scientists have essentially investigated the plastic pollution at the sea surface. However, some mixing at the surface is induced by wind and waves, which moves this pollution in depth. In this work, we focus on the vertical transport of micro-plastics offshore, which are more sensitive to this vertical transport due to their low buoyancy (being small size). Their dynamics is described by a balance between an upward flux due to plastic buoyancy and a downward flux due to turbulence. We study their vertical distribution thanks to samples collected at sea and laboratory experiments, in which, micro-plastics are modeled by particles with regular shapes (spheres and disks). The surface turbulence, which mixes them in the water column, is generated by an oscillating grid system to mimic the turbulence decay with depth.



From plastic debris to models | Rise velocities | Microplastics corrected concentrations

First, we propose a model for the rise velocity (buoyancy) of the micro-plastics, taking into account their properties (density, size and shape). Given the wide range of plastic properties, we propose to encompass their rise velocity by an upper and a lower bound for each range of size. These bounds comes from a choice of two densities and regular shapes, based on a statistical analysis of the properties of 400 samples collected in the Atlantic North Gyre in 2015.

Second, the characterization of the flow used in laboratory experiments is done using Particle Image Velocimetry (PIV) technique. The oscillating grid turbulence is studied in both homogeneous and two-layer fluids. A parametric law for the eddy viscosity, taking into account the turbulence decay with depth, is proposed. This approach, giving a general description of the flow, is new. Indeed, oscillating grid turbulence is usually described in terms of turbulent kinetic energy and dissipation rate.



Third, the vertical distribution of buoyant particles is investigated in oscillating grid turbulence experiments. It is obtained thanks to measurements in two dimensions unresolved in time (in a laser sheet) and measurements in volume resolved in time (Particle Tacking Velocimetry and

stereoscopy). Coupling them with the characterization of the flow, we describe the vertical transport of plastic using the " $k - \varepsilon$ " turbulent model. We provide the first estimation of the turbulent Schmidt number for finite size particles with low inertia ; the turbulent Schmidt number being the key parameter for the fluid-particles coupling in such approaches.

Main scientific recommendations :

- Sampling in depth and not only at the surface. This should ensure more representative figures for small micro-plastics (< 1 mm) collected and a better description of the plastic pollution when the sea is rough (Beaufort 3 and more).
- Take into account the large range of micro-plastic's size and shape in correction models for surface measurements, like we propose.
- Take into account the turbulence decay with depth. Indeed, the shape of the concentration profile with depth of micro-plastics depends on it. In some cases, this can lead to different types of profiles compared to the commonly used exponential decay. The explicit calculation of the concentration profile, using the value for the turbulent Schmidt number identified in this work, is then necessary.

Key words : Micro-plastic particles - Turbulence - Buoyancy - Vertical transport – Stratification