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THE DELTA TRANSPORT PROCESSES LABORATORY: LAB FOR SURFACE AND INTERNAL WAVE-INDUCED CURRENTS UNDER ROTATION

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1 INTRODUCTION

The presence of marine pollutants such as marine plastics has increased significantly over the last decades and poses a major environmental problem, in both the coastal and offshore area. Marine pollutants are transported, mixed and diffused in the ocean, which means the understanding and modelling of marine transport is key for mitigation purposes (Moulton et al., 2022). Additional to large scale and planetary currents that play a major role in marine transport, free surface waves, internal gravity waves in density stratified fluids and the Coriolis force due to the rotation of the Earth are also fundamental drivers of transport that need to be accounted for. The fundamental fluid mechanics processes associated with these are often not resolved in large-scale models, but are instead included in a parametrised form. However, some fundamental processes associated with wave-induced currents (*e.g.*, Stokes drift) in rotating, density-stratified fluids with a free surface remain unclear and untested. In addition, parametrisation for different environments, forcings and time scales must be developed and tested before being implemented into models for them to reliably predict transport, accumulation and storage of marine pollutants. For this purpose, the Delta Transport Processes Laboratory (DTPLab) is being developed at TUDelft Hydraulic Engineering Laboratory. This laboratory pioneers the combined experimental study of surface waves, density stratification and Coriolis forces in a single laboratory. The DTPLab was designed with a multi- users and purposes vision, with interchangeable facilities and state-of-the-art measurement devices. This paper presents the DTPLab facilities (under construction) and equipment that make this laboratory unique in the world, and describes, as an example of what is feasible, a novel experiment that will be performed in this lab.

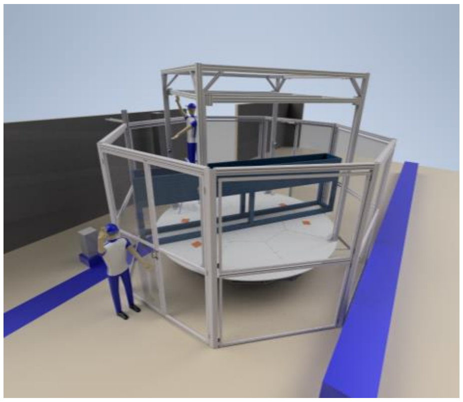
2 THE DTPLAB

2.1 Rotating Table

The primary facility of the DTPLab is a rotating table of 4.40 m in diameter (Figure 1), which makes it the second largest active rotating table in the world. The rotation speed of the table ranges between 0.4 and 7.5 rpm, with high controllability and stability and nearly zero vibration. The table can support a load of 10 tons, and can thus accommodate basins, flumes and all sorts of equipment. The table is fully autonomous and powered, meaning that instruments can be installed on the table and rotate with it. Instruments such as cameras can be fixed on the table or an overhead frame sitting 3 m above the table. Connection with instruments on the table can be done via Wi-Fi or ethernet, using computers placed on a working platform from which the users can operate.

2.2 Wave flumes

The DTPLab has 2 wave flumes: one of 5 m and one of 13 m long. They are both 0.5 m heigh, 0.5 m wide and are elevated by 0.9 m above the floor with optical access from all sides (bottom and walls are made of toughened glass). They are both equipped with drainage and filling system, side wall rails and are salt resistant so that density stratification can be created. The 13 m long flume is permanently fixed in the lab, while the 5 m flume is compact and liftable so it can be placed on the rotating table. A selection of beach slopes and beach absorbers are available to use in both flumes, and for both deep water, coastal or internal wave experiments. In association with the flumes, a network of automatised pumps and reservoirs are available to create a custom density stratification for the study of internal gravity waves.



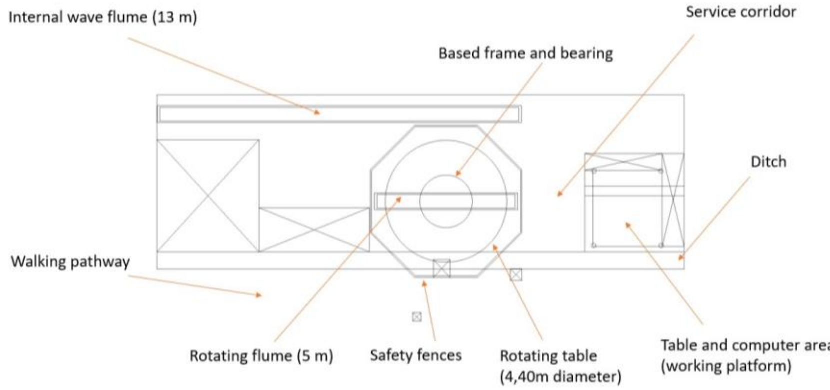


Figure 1. *Left*: Schematic design drawing of the rotating table, safety fences, overhead frame (grey and white parts), 5 m long flume (on top of the table in black) and 13 m long flume (in blue); *Right*: Floor plan of the DTPLab.

2.3 Wavemakers

The DTPLab has 2 wavemakers that can be installed in both flumes. One consists of a piston-type surface wavemaker, able to generate waves in both deep, intermediate and shallow water. This wavemaker can generate regular and irregular waves as well as wave packets, with second order wave generation. It is equipped with an active reflection compensation system that accounts for short and long waves that have reflected from the other flume's end. The wavemaker can operate in 0.10 to 0.40 m water depth, generate waves height up to 0.10 m and with wave period comprised between 0.5 and 2 s (0.5-2 Hz).

The second wavemaker is used to generate internal gravity waves in any type of density stratification. Its concept is based on the system developed by Gostiaux et al. (2006) which, shortly, consists of a stack of thin plates and cams linked through by a camshaft that can rotate at different frequency. To overtake the limitation of such a system (*e.g.*, fixed eccentricity, periodic plate profile), the current wave maker will have each plate independently activated by a step motor, so that the frequency and eccentricity of each plate can be set independently from each other. This new system will allow the user to vary both the frequency and amplitude over time, enabling the generation of interfacial wave packets (*i.e.*, irregular waves) in multilayers stratification and multimodal internal gravity waves in continuous stratifications.

2.4 Flow visualisation

Beyond classical laboratory instrumentation such as wave gauges, LiDARs or ADVs, the DTPLab has a dedicated 3D Particle Tracking Velocity (PTV) system (MiniShaker from *La Vision*) along with the state-of-the-art 'Shake-the-box' software data processing. This high speed flow visualisation system can track thousands of particles in a 3D illuminated fluid volume, and record their trajectory to obtain the Lagrangian velocity measurement. Eulerian velocity can also be reconstructed, allowing a complete 3D analysis of flows and turbulences at high resolution. In addition, the MiniShaker system – a compact case of 4 cameras at fixed angle – simplifies and fastens the experimental set-up and calibration, and this regardless the expertise the users has with PIV/PTV systems.

3 A NOVEL EXPERIMENT IN THE DTPLAB

The first experiment to be conducted in the DTPLab will investigate the impact of the Coriolis force on the Stokes drift, to better understand wave-induced currents dynamics and interactions. The experiment will focus on both deep, intermediate and shallow water regimes, under different surface wave forcing conditions and time scales. The set-up used for this experiment is displayed in Figure 1: the 5 m wave flume will be installed on the rotating table and measurements will be performed with the 3D PTV system. The conceptual approach of this set-up is to work at a scale where the rotation does not affect the wave field, but does influence the wave-induced current field. The experiments are expected to validate the theory around the concept of a 'circle of inertia' (Hasselmann, 1970), and bring a better understanding of Eulerian currents interactions under rotation and total mass transport.

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