Organisation Plume

-First set of Experiment-

AVRIL 2024

General information

This set of experiments is the first set planned in Task 1.1 of the PLUME project led by B. Deremble. **A second set is planned for 2025**, the more precise timetable has yet to be specified.
There are two different configurations in this set. The first being the lightest and not described in the ANR project presentation

- This first configuration (**KP**) is designed to reproduce the KATO-PHILLIPS experiment in the Coriolis platform. We will perform spin-up experiments either from a non-rotated state ($T_{rot} = \infty \rightarrow T_{rot} = 120\,\mathrm{s}$) or from a solid body rotation ($T_{rot} = 120\,\mathrm{s} \rightarrow T_{rot} = 60\,\mathrm{s}$). The purpose of this experiment is also to test the robustness and lifetime of temperature stratification ($T_h = 40\,°\mathrm{C}$ and $T_c = 15\,°\mathrm{C}$), to obtain the physical alterations that this implies for the platform and then to test the Kato-Phillips experiments with temperature stratification (establishment of a mixing layer during a Spin-Up). **It should be noted that these experiments in this configuration are very short ($\sim 100\,\mathrm{s}$) and that each experiment done with a stratification, destroys it**.
- The second configuration (**RB**) involves the installation of a heated floor, a horizontal sheet laser with an oscillating mirror to obtain a vertical scan, a vertical sheet laser (in a configuration similar to the previous configuration) and a cylinder with an internal radius of 2.5 m. These experiments are described on p7 of the ANR project and below. These experiments are the core of the project and are designed to observe convection in the platform due to heating (head-down configuration with respect to the ocean) and to isolate characteristics according to the environment (stratification, rotation, stress).

Preliminary agenda

5 April 2024 : First configuration installation (KP)
8 April - 3 May : KATO-PHILLIPS experiments

6 may - 24 May : Second configuration installation (RB)
27 May - 2 August : Plumes experiments
2 August - 16 August : Summer Break
19 August - 30 August : Last experiment on configuration 2

1. Experimental configuration (KP)

The (KP) experiment seeks to observe the formation of a layer of frictional mixing due to the spin-up of the platform. the aim is to build up temperature stratification and rotate (or accelerate the rotation of) the platform.
- An exel "Planning plume" document has been uploaded to the PLUME24 space, describing the experiment with initial and final rotation Time, the stratfictaion (cold and hot temperature), an approximation of the experiment time, the expected friction velocities, the positioning of the laser slice and the ADVP (or ADV). This document is an outline and gives the general framework.

Task

1. Perform a set of experiments without stratification by varying the distance of the ADVP (ADV) from the wall. The experiment can be sequenced in a row :
   — Spin up of the platform ($T_{rot} = \infty \rightarrow T_{rot} = 120\,\mathrm{s}$)
   — Wait (with help) for the solid body rotation
   — Spin up of the platform ($T_{rot} = 120\,\mathrm{s} \rightarrow T_{rot} = 60\,\mathrm{s}$)
   — Wait (with help) for the solid body rotation
   — Spin up of the platform ($T_{rot} = 60\,\mathrm{s} \rightarrow T_{rot} = 40\,\mathrm{s}$)
   — Wait (with help) for the steady state ($T_{rot} = \infty$)
   — Mouving the ADVP
   — Redo the experiment
   Some PIV can be done if compatible with the ADVP

2. Establish a linear Thermal stratification ($T_h = 40\,^\circ\mathrm{C}$ and $T_c = 15\,^\circ\mathrm{C}$) over $H = 50cm$ and measure with conductivity probes the time evolution of the stratification over time (and space) (**Experiment can be done during the Weekend or the night**)
3. KP- Experiment with vertical PIV and stratification (mostly in T but for a few in salt) following the Exel doc. A colorant would also be injected (at the bottom) on the very last moment of filling (observation of the growing frictional layer)
   — Create a stratification in temperature (A stratification in salt will be done after)
   — Measurement of the vertical profile of temperature over at least two probes (horizontal homogeneity)
   — PIV/(ADVP) particle seeding
   — Rotation (or acceleration)
   — Use of two cameras for high resolution close to the bottom ($\sim 20cm$) (Reynolds tensor measurement) and an other more global view (50cm)

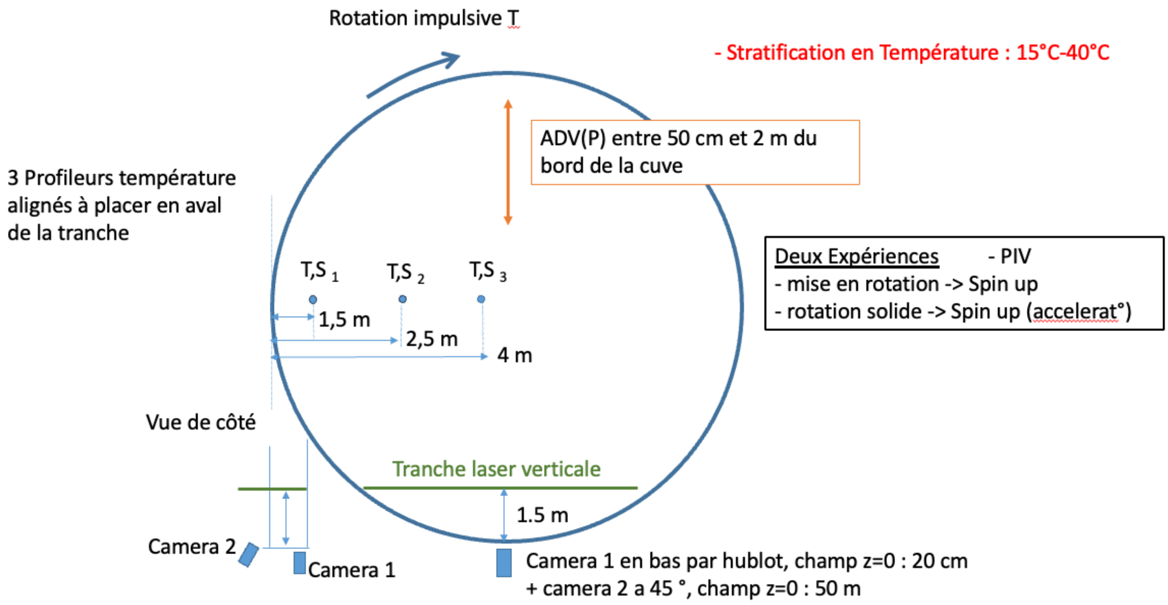

FIGURE 1 – Scheme of the first configuration (KP)

2. Scientific consideration

The aim of these experiments is to impose friction on a water column that simulates a uniform and rectilinear stress (the consequences of the circular geometry of the platform are expressed below).

This therefore corresponds to forced convection without heat flux. The stress is obtained by a difference in rotation speed between the platform and the water column. This speed differential can therefore be positive (Spin-up), i.e. the platform is rotated relative to a column of water at rest or accelerates its speed of rotation in the same direction as the column. This differential can also be negative (Spin-Down) if the platform slows down its speed. In order to remain consistent for all experiments, we will only perform Spin-up. In addition, the effects of spinning up and spins down are not the same, as the instabilities created by a spin up are not the sames of those created by a spin down (see Sous et al 2013).

In these experiments, it is planned to observe several processes, and to combine them in order to study the interactions between these processes. In general, we will be interested in the growth of the boundary layers (frictional and mixing layers) with the three following processes, all in a turbulent regime :
- No stratification or stratification of a more or less strong type (thermal or salt)
- The effect of rotation on the growth of the mixing layer and a turbulent Ekman layer
- The dependence on the Prandtl number which depends on the diffusivity of the water (salt or thermal)

2.1. Measure of the Reynolds Tensors - ACVP

The advantage of using an ACVP-type acoustic profile is to obtain a measurement of all three velocity components over the entire water column. From this we can deduce the

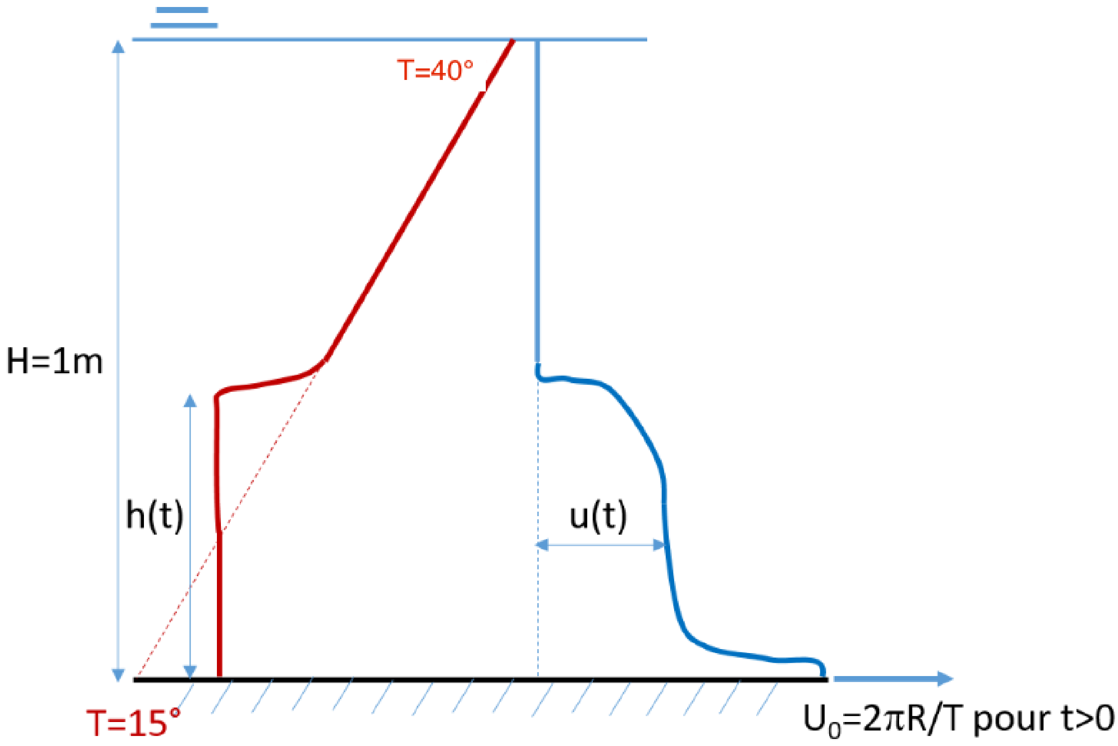

FIGURE 2 – Velocity and density profiles, note that H can be different

turbulent correlation terms.

2.2. Growth of the mixed layer

2.3. Influence of the rotation

2.4. Dependence in the Richardson number

$$Ri = N^2 \left(\frac{dU}{dz}\right)^{-2}$$

with $N = \sqrt{-\frac{g}{\rho_0}\frac{d\rho}{dz}}$ the Brunt-Väisälä frequency (unit s^{-1}) and $\frac{dU}{dz}$ the shear stress (unit s^{-1})

The number we will use is slightly different :

$$Ri_o = N^2 \frac{h^2}{2u_*^2}$$

With h the height of the ML

In their experiences *Kato and Phillips* have explored the ratio between the entrainment velocity u_e and the friction velocity u_* over a range of Ri_o which goes from [20 to 300]. In our case. Thermal stratification will be much weaker than theirs (5 per/1000) compared with (5 per/100) for salt stratification. We can therefore obtain much lower values of Ri_o (of the order of $Ri = 1.4$). Hence we should be approaching the case of a passive scalar.

2.5. Dependence in the Prandtl number

$$Pr = \frac{\nu}{\kappa}$$

with ν the kinematic viscosity (unit $\mathrm{m}^2\ \mathrm{s}^{-1}$) and κ the molecular diffusivity (unit $\mathrm{m}^2\ \mathrm{s}^{-1}$) An original question would be to see whether the entertainment process is independent of molecular diffusivity. To do this, we will carry out experiments at different Prandtl numbers. Experiments with salt correspond to Prandtl numbers in excess of 1000, whereas numerical simulations are always limited to Prandtl numbers of the order of 1, which is also the order of magnitude for thermal stratification.

To our knowledge, this dependence has never been studied.

Sources : *Turner - The influence of molecular diffusivity on turblent entrainment across a density interface, 1968*

2.6. Theory :

we are Interested in the growth of the mixed layer, and in the thikness of th turbulent ekman layer

Radial effects

Voir papier Boldvald, Inuyama, Flor x2