Sedimentation of cloud of particles in vortex flows

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Particles flows are present in several natural and industrial processes. Transport of sediments in rivers and estuary, pollutants in atmosphere, zooplankton bio convection, gravity flow and turbidity near coast, pyroclastic flows during eruption of volcanos are examples that we can find around us. In industry, processes involving particles flow are also widely found: fluidized bed reactor, water treatment, food industry, pharmaceutical or cosmetic. For all these examples, particles sedimentation is a dominant complex phenomenon which is essential to control and equally important to understand fundamentally.

Many works were investigated in a quiescent fluid. Some concerned a diluted suspension [1], [2]. In these works authors have worked on the interface at the top of the suspensions. They observed that the width of the front grow linearly in time, due to a polydispersity of particle size and due to fluctuations in particle density. Others works have been focused on the sedimentation of a cloud of particles at low Reynolds number: in a viscous fluid, i.e. a low Stokes number, [3], and for more inertial condition [4]. For both break up were observed, depending of the number of particle in the initial cloud. This instability starts by shaping the cloud in a torus which breaks up into secondary droplets that deform into tori themselves in a repeating cascade. The nature of the breakup of the torus is found to be intrinsic to the flow created by the particles when the torus aspect ratio reaches a critical value. More inertial is the fluid condition, greater is the role of the flows, created by the particles, in the break up process.

Sedimentation in a vertical flow was also undertaken in [5] for one particle at low Stokes number. It showed that particle velocity can be considered as the sum of the particle Stokes velocity and the local velocity of the surrounding fluid. At low Stokes number, only the Stokes drag force can be used to simulate the particle trajectory. Good agreement is found between numerical and experimental results.

The combination of cloud of particle and a vortical flow has never been investigated. This work highlights the following questions: (1) How will a cloud behave in this condition? (2) Will a break up take place? (3) Is the physical mechanism the same as that in a quiescent fluid? (4) How will the cloud interact with the flow? (5) Will it stays a compact entity or not?

We present a jointed experimental and numerical study examining the influence of vortical structures on the settling of a cloud of solid spherical particles under the action of gravity at low Stokes numbers. The two-dimensional model experiment uses electro-convection to generate a two-dimensional array of controlled vortices which mimics a simplified vortical flow. Particle image-velocimetry and tracking are used to examine the motion of the cloud within this vortical flow. The cloud motion is compared to the predictions of a two-way-coupling numerical simulation.

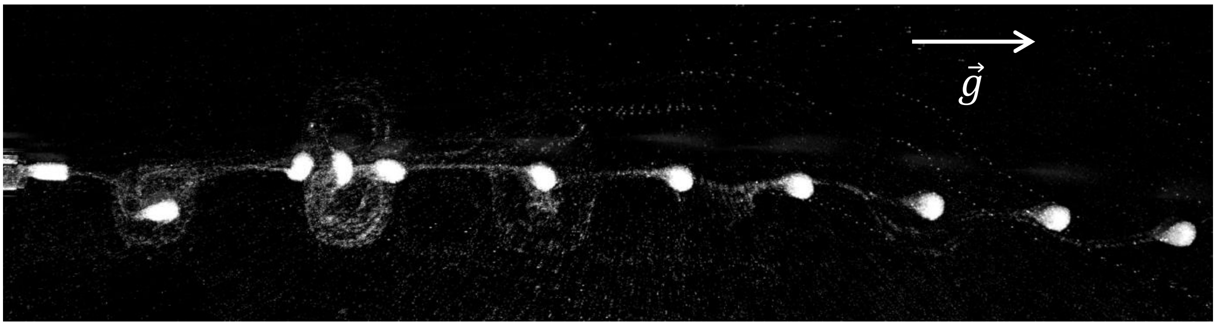

Figure 1 - Position of a cloud of particles in a vortical flow at different times

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