Dynamics of a reactive spherical particle falling in a linearly stratified layer

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Rocky planets such as Earth, Mercury or Ganymede have a liquid iron core which may be totally or partly stably stratified [1,2]. The sedimentation of iron particles crystallizing due to the secular cooling of the planet [3] or the precipitation of oxides [4] implies complex dynamic features involving a turbulent wake, the generation of internal waves, collective behaviour of the solid crystals, etc. It also involves reactive solid particles which may crystallize/melt.

Beyond the geophysical application, this problem is, therefore, related to several current problems in fluid dynamics, which we address with the help of a laboratory-scale experiment. The behaviour of a particle falling in a stratified layer has already been studied for different regimes of small Reynolds or Froude numbers [5,6]. However, the influence of a reactive particle on a stratified medium has been unexplored, especially for regimes of interest for geophysical applications (large Reynolds and Froude numbers). In a stratified environment, the fall velocity is reduced due to the higher drag coefficient. During its fall, a particle drags a less dense liquid mixed with the product of the melting/dissolution. Then, the drag coefficient depends on the mixing in the wake, and on the melting/dissolution rate.

I am conducting experiments in a large water tank with salinity stratification where an icy, salty sphere is released from the top. I use two cameras and particle image velocimetry (PIV) to track the fall of the particle and the dynamics of the surrounding environment. I examine the velocity and the rate of dissolution of the spherical particle in comparison to a theoretical model. I also characterize the influence on its surrounding environment - generation of internal waves, the quantity of energy dissipated, and the mixing of the stratified layer. All these quantities are non-linearly coupled, leading to complex and interesting dynamics.

Références

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