Wakes generated by vertical flow past cylinders in stratified fluids (Alexis Kaminski)

The problem of horizontal flow past spheres and cylinders has been studied in a wide variety of contexts. In contrast, relatively little attention has been paid to the problem of vertical flow past solid bodies, particularly in stratified fluids. These types of flows can arise in a variety of settings, from the motion of aerosol particles or zooplankton at small scales to oceanographic floats measuring fluid properties at depth [3,5].

For vertical stratified flow past spheres, a wide variety of different wake structures has been observed (figure 1a). These wake structures depend on the flow Reynolds number $Re=Wa/\nu$ and Froude number $Fr=W/Na$ [3], as well as the Schmidt number of the fluid $Sc=\nu/\kappa$ [4], where W is the vertical velocity of the sphere, a is the sphere diameter, ν is the kinematic viscosity, κ is the scalar diffusivity, and N is the buoyancy frequency. These different wake structures can lead to different drag coefficients [5]. Results from descending spheres has been used to describe the drag in the control systems for Lagrangian oceanographic floats. However, many uncertainties remain (particularly in strong stratification), including how the drag law depends on the float shape [2].

In this project we will consider the wake structures that arise from vertical stratified flow past an elongated body, such as a finite-length cylinder or ellipsoid. This will be done via axisymmetric simulations in Dedalus [1], shown schematically in figure 1b. The dependence of the wake structure on the flow parameters will be examined (as for spheres), as well as the additional dependence on the aspect ratio of the body L/a.

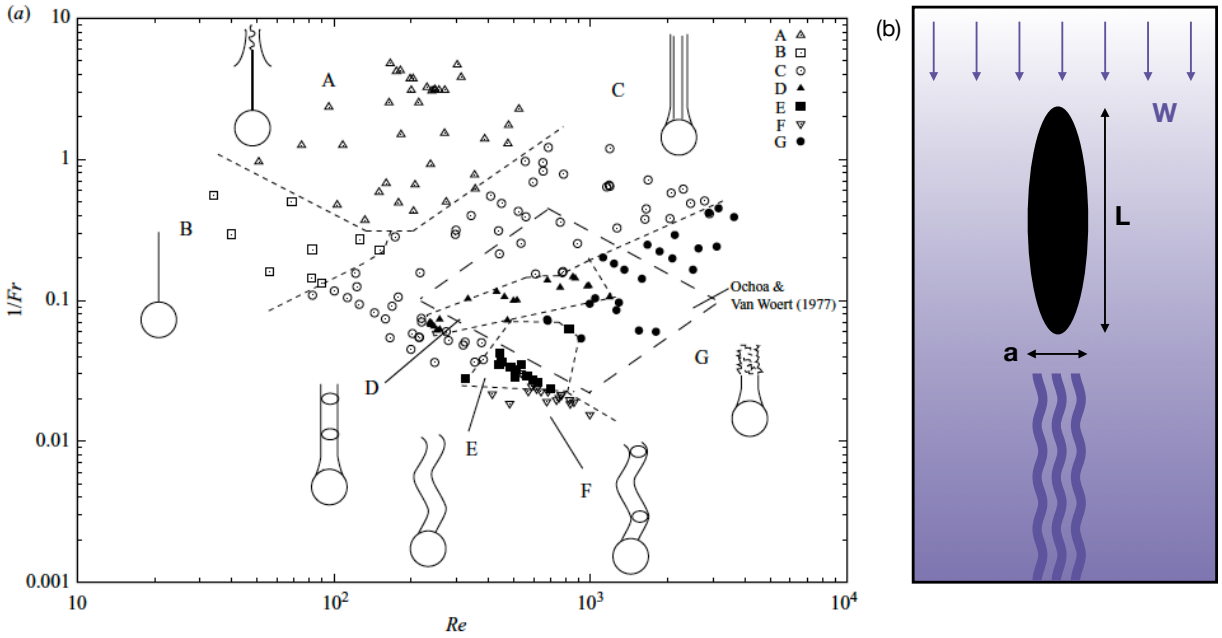

Figure 1. (a) Different wake structures possible for flow behind spheres moving vertically in uniform stratification, depending on Re and Fr (from [3]). (b) Schematic for proposed simulations.

References:

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[2] D'Asaro, E. A. Oceanographic floats — principles of operation. In Venkatesan, R., Tandon, A., D'Asaro, E., and Atmanand, M. A. (Eds.), *Observing the oceans in real time — instruments, measurements, and experience*. Springer Oceanography, 2018.

[3] Hanazaki, H., Kashimoto, K., and Okamura, T. 2009a Jets generated by a sphere moving vertically in a stratified fluid. *J. Fluid Mech.* 638, 173-197.

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[5] Torres, C. R., Hanazaki, H., Ochoa, J., Castillo, J., and van Woert, M. 2000 Flow past a sphere moving vertically in a stratified diffusive fluid. *J. Fluid Mech.* 417, 211-236.