Fluid Dynamics of the Environment (L24)

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Understanding the environment and predicting the impact of human activity on it are critical challenges in our time. Whether we are concerned about climate change, pollution or the spread of infectious aerosol droplets within our buildings, fluid dynamics plays a vital role. This course explores the basic fluid dynamics necessary to build mathematical models of the environment in which we live, focusing on problems which occur over sufficiently small time and length scales to be largely unaffected by the earth's rotation.

The course begins by considering fluid flow in the presence of (typically small) density variations. If the fluid is stably stratified, 'internal gravity waves' can occur since the stratification provides a restoring force when fluid parcels are displaced vertically. The course highlights some of the rich and surprising dynamics of these waves. For example, internal gravity waves radiate energy vertically as well as horizontally, and their interaction with boundaries can focus this energy and cause mixing far from where the energy was input.

Density variations within fluids can also drive the flow and the course will consider two important related cases, where the flow is either tall and thin or long and shallow. Both cases allow substantial simplification of the governing equations by integrating them over the smaller dimension. One example of the first case is the flow from a localised source of buoyancy that can lead to the formation of a tall, thin buoyant plume moving vertically away from the source. Volcanic eruption clouds and the thermal plumes we each produce are just two examples of this wide-spread mechanism. Turbulence, entrainment and mixing play an important part, as does the stratification of the fluid into which they move. Examples of long and shallow flows include gravity currents, again driven by density differences, but this time in the presence of boundaries or large changes in the density of a stratified ambient fluid. In such cases, waves on the interface that develops play an important role in governing the behaviour of the flow. Such flows develop, for example, when you open the door on a cold day, or as a particle-laden pryoclastic flow from a volcanic eruption. When confined by geometry, the combination of both these limiting cases plays an important role in determining the ventilation of a room and hence one of the potential mechanisms for transmission of airborne infections.

Pre-requisites

Undergraduate fluid dynamics is desirable.

Literature

Reading to complement course material

1. B. R. Sutherland, Internal gravity waves, Cambridge University Press (2010).
2. J. S. Turner, Buoyancy Effects in Fluids, Cambridge University Press (1979).
3. J. Pedlosky, Geophysical Fluid Dynamics, Springer (1987).

Additional support

In addition to the lectures, four examples sheets will be provided and four associated examples classes will run in parallel to the course. There will be a revision class in the Easter Term.