Fluid Dynamics of the Environment (L24)

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Understanding the environment is a critical challenge. Whether we are concerned about climate change, pollution or sediment transport, the high-Reynolds-number fluid dynamics of buoyant flows plays a vital role. Here we focus on flows that occur over sufficiently small time and length scales to be largely unaffected by the earth's rotation. These are the scales in which we live, and hence we experience – and sometimes effect – these flows directly.

The course will begin by considering shallow water flows, a class of 'thin' flows where near-horizontal motion is driven by density differences. These shallow flows can be steady or time dependent, with the density differences arising from temperature, composition, suspended particles, or combinations of these. The cold air entering a room when you open the door on a cold day and the dust cloud from demolishing a building are just two examples. The flows can propagate along interfaces within the fluid, horizontal boundaries or sloping boundaries. In many cases, especially as the slope of the boundary increases, turbulence plays an important role, reducing the density differences driving the flow.

Thin flows also arise where there is a localised source of buoyancy without a boundary along which it can flow. Rather than forming a near-horizontal shallow water flow, a vertical flow in the form of a buoyant turbulent plume or a buoyant thermal develops. Such flows are widespread in both the natural and built environment (e.g. from a volcanic eruption or above a radiator in your college room).

Drawing together these thin flows, we will delve further into the fluid dynamics of indoor environments. With an increasing fraction of the world's population residing in cities and spending 90% of their time indoors, creating sustainable urban spaces is essential. Combating the climate crisis through decreasing energy consumption is one imperative, but another is improving indoor air quality due to its impact on many aspects of health and productivity. As poor ventilation played an important role in disease transmission during the recent Covid-19 pandemic, we introduce approaches to modelling the airborne transmission that is is important for many of the most infectious diseases.

Although this course is not primarily about turbulence, we find that turbulence inevitably plays a role in both indoor and outdoor environmental flows and so we shall touch on key aspects of turbulence and how it is modified by stratification at various points during the course. Additionally, we shall explore the propagation of energy by internal gravity waves that can form within a stratified fluid.

Prerequisites

Undergraduate fluid dynamics is desirable.

Literature

- J. S. Turner, *Buoyancy Effects in Fluids,* Cambridge University Press, 1979.

Additional support

Four examples sheets will be provided and four associated examples classes will be given. There will be a one-hour revision class in the Easter Term.