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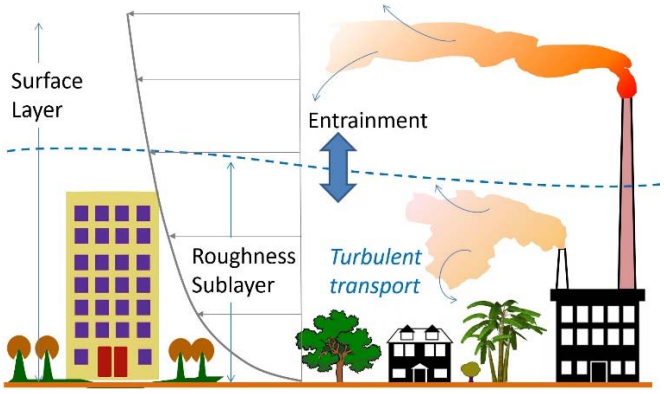
Dispersion in atmosphere

Civil engineering application or problem

Consider an example of exhausts from motor vehicles that accumulate inside a road tunnel. The emissions are typically drawn outwards using suction fans and released to the atmosphere via chimney-like exhaust stacks. Such ventilation stacks are usually located in the midst of residential areas and it is critical to ensure that pollutants are not carried closer to Earth's surface by ambient winds (see figure below). Failure to do so can result in poor air quality and undesired long-term health effects on nearby residents as pollutants can remain trapped within the urban roughness sub-layer (first few metres adjacent to the surface).



Significance

A recent study estimated 1,483 deaths occur per year in Australia due to outdoor air pollution in 2010, compared to 882 deaths per year in 2005 [1], an increase of 68%. Ambient particulate matter pollution is ranked 9th amongst 67 risk factors contributing to the global disease burden [2] and cause of health problems such as respiratory illness, cardiovascular disease, childhood asthma, and cancer, due to long term exposure to emissions, which have steadily increased in the Australian environment. Considering over 50% of Australia's population resides in five major cities and in close proximity of pollution hotspots, it is crucial to accurately predict the spread of pollutants (also referred to as scalar or contaminant) due to winds over Australia's characteristic topography.

Role of fluid mechanics

Turbulence in the lower part of the atmosphere plays an important role in transport of contaminants (or pollutants). A contaminant is any substance that makes the background fluid impure. Contaminants spread in a fluid flow by two mechanisms, the molecular diffusivity and the convective transport due to background flow field. Molecular diffusivity is a relatively slower than convective transport, especially in turbulent flows. In case of turbulent flows, eddying motions are responsible for rapid mixing of a contaminant into its surrounding, e.g. stirring of milk in coffee. Since turbulent flows are not predictable, one has to rely on computational methods to estimate spread of contaminants.

Reference(s)

[1] OECD. The cost of air pollution: Health impacts of road transport. OECD Publishing, Paris, 2014. DOI:http://dx.doi.org/10.1787/9789264210448-en.

[2] S. S. Lim, T. Vos, A. D. Flaxman, G. Danaei, K. Shibuya, H. Adair-Rohani, M. A. AlMazroa, M. Amann, H. R. Anderson, K. G. Andrews, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the global burden of disease study 2010. The Lancet, 380(9859):2224–2260, 2013.