I. P. Castro & C. Vanderwel, *Turbulent Flows: An Introduction*, IOP, 2021.

Chapter 9 Sample Exercises

9.1 Estimate the diffusion timescale $t_{\text{diff}} = L^2/(8\gamma)$ (eq 9.7) representing the time it would take for the diffusion of milk in a cup of coffee in the absence of advection, choosing appropriate values for L and γ.

9.2 Plot the concentration profiles $c(x)$ for a single point source puff of mass $M = 1$ kg released in an ambient fluid without any advection, assuming $\gamma = 1$ m^{2}s^{-1}. Compare the rate of decay of the maximum concentration for 1D, 2D, and 3D scenarios.

9.3 Plot the evolution of an instantaneous 1 kg point source released at the origin in a uniform flow with $U = 1$ ms^{-1}and $\gamma = 1$ m^{2}s^{-1} at several time steps. Compare the level of concentration with the scenario of a continuous 1 kgs^{-1} point source released at the origin under the same conditions.

9.4 The files "PlumeData1.txt" and "PlumeData2.txt" each contain a dataset containing 1000 samples of all three velocity components, U, V, and W (in mm/s), and concentration, C (normalised by the source concentration so it is unitless), all measured at 2 Hz (i.e. not time-resolved). The two datasets were collected from two points at the edge of a thin continuous point-source plume at locations of $y_1 = 16.1$ mm and $y_2 = 18.5$ mm measured from the centreline of the plume, respectively.

a. Calculate the mean concentration at each point. From this, determine the vertical gradient of the mean concentration between these two points.

b. Plot a scatter plot of the concentration fluctuations versus fluctuations in the vertical velocity component at both points. Does this indicate a positive, negative, or neutral correlation?

c. Calculate vertical turbulent concentration flux $\overline{cv}$ at both points and report the average. Explain the significance of this term.

d. Using the first-order gradient transport model, determine the turbulent diffusivity, γ_T (including units). The intermittency of the concentration signal creates some uncertainty in the result - estimate the range of confidence in this result.