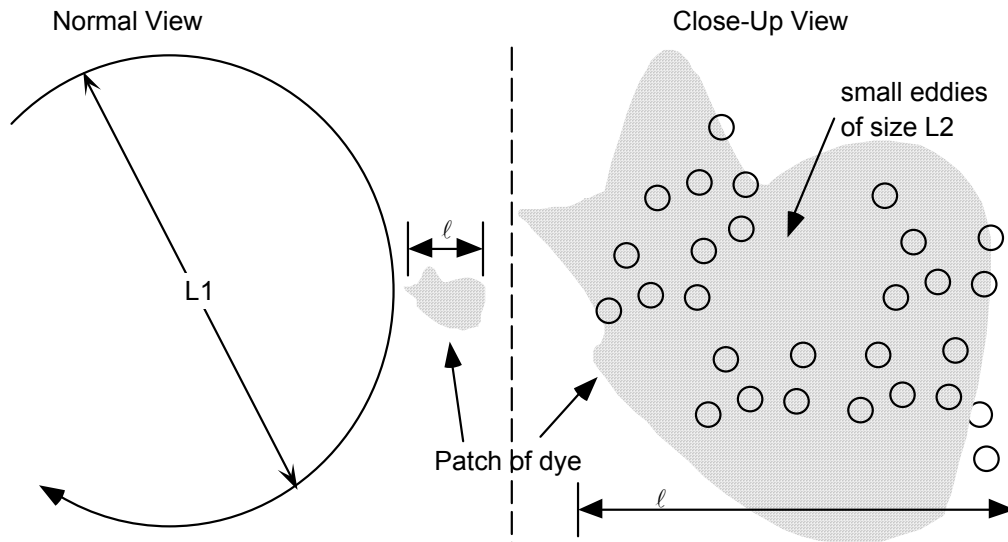


Problem 1 [4 points]:

A patch of dye is released into the middle of the ocean. The patch size is ℓ .

- How do eddies of scale $L1 \gg \ell$ interact with the patch.
- How do eddies of scale $L2 \ll \ell$ interact with the patch.



Problem 2 [6 pts]: During rain storms the street run-off is conveyed to a river by a concrete culvert. During a large storm event a peak flow of $q = 0.5 \text{ m}^3/\text{s}$ in the culvert and $Q = 4.5 \text{ m}^3/\text{s}$ in the river upstream of the culvert are maintained for 36 hours. During the early part of the storm, the street run-off contains fine sediment with high metal content, $C = 500 \text{ g/m}^3$, which persists for 16 hours, starting 1 hr after the peak storm flow is reached. After that time the streets are washed clean and the concentration in the run-off drops to zero. Assume that the particles are sufficiently fine that they are transported with the flow without settling, *i.e.* they behave like dissolved species. During the storm the river has width $B = 10 \text{ m}$; depth $h = 2 \text{ m}$; isotropic turbulent diffusion $D = 0.05 \text{ m}^2/\text{s}$; and longitudinal dispersion $K_x = 0.5 \text{ m}^2/\text{s}$. Follow these steps to estimate the maximum sediment concentration observed at $L = 2 \text{ km}$ downstream of the culvert inflow. Assume the culvert inflow enters the river at $x = 0$.

- At what distance downstream will the culvert inflow be mixed across the river cross-section?
- What time scale describes the transport between the culvert and $x = L$?
- Should the release of sediment be considered an instantaneous or continuous release?
- Starting with the full transport equation $[\partial C/\partial t + \dots]$ derive an expression for metal concentration at $x = L$ during the steady portion of the release. State and justify all assumptions.
- Sketch the metal concentration $C(t)$ at $x = L$ during the peak flow. That is, $t = 0$ should be the beginning of the peak flow. Include the unsteady period at the front and end of the exposure

period by showing the length of the front and tail and the time at which the center of the front and tail arrive at $x = L$.