CE 37200: Environmental Impact Assessment

Homework 3
Chapter 5 (mass balance and box models)
Due: Mar. 6

1) A lake has a box shape, and extends over $0 < x < 1000$ m, $-50 < y < 50$ m, $0 < z < 10$ m (where higher z is down). There is an inflow of 5 m^3/s located at x = 0, y = 0, z = 0. The outflow is at x = 1000, y = 0, z = 0, and the amount of water in the lake is constant over time. The inflow contains 10^{-6} M dissolved nitrate (NO_3^-), and nitrate is removed by a first-order reaction with 1/k = 1 day.
(a) Find the steady-state nitrate concentration in the lake with the given inflow and outflow, using a 0-D box model.
(b) Find the steady-state nitrate concentration in the lake with the given inflow and outflow, using a 1-D model (non-uniform in the x direction).
(c) Plot the profile of nitrate concentration versus x from both the models in parts (a) and (b).
(d) Starting from the steady-state situation found in (a), assume that it rains for 24 hours over the lake at the rate of 1 mm/hour, and that the rain contains 10^{-4} M nitrate because of smoke from a nearby fire. Find the nitrate concentration in the lake as a function of time during the rain and for 3 days afterward, using a 0-D box model. Plot the profile of nitrate concentration versus t.

2) The winter surface boundary layer is 500 m high over a circular city that has a radius of 10 km. There is a steady wind blowing in the x direction across the city, with velocity increasing with height within the boundary layer as $V(z) = z^{0.3}$, where z is in m (ranging from 0 to 500) and V is in m/s. The average pressure in the boundary layer is 980 hPa and the temperature is 270 K. The upwind concentration of SO_2 (sulfur dioxide) in the air is 5 ppbv. SO_2 is emitted within the city limits at an average rate of 10^5 mol/hour, primarily from furnaces burning heating oil. SO_2 is removed by a first-order reaction with 1/k = 1 hour.
(a) Find the steady-state SO_2 concentration over the city, using a 0-D box model.
(b) Suppose that a tanker truck driver strike interrupts the supply of heating oil to the city. While this leaves a lot of cold people, a benefit is that SO_2 emissions immediately drop by half. What is the new steady-state SO_2 concentration, after the strike has been going on for a long time? What is the time constant for how long it takes to approach the new steady state?