MSc in Computational Fluid Dynamics

Atmospheric Dispersion

Assignment 2

For the second assignment, choose one of the following:

(a) Mixing Height and Buoyant Plumes

It is often the case that vertical mixing in the atmosphere is limited to a region close to the ground (up to a few hundred metres or perhaps one or two kilometres). Thus, a pollutant from a localised source will not continue to mix vertically as it is transported downstream. Eventually, far downwind, the pollutant will have mixed throughout the layer near the ground and further dispersion can then only take place horizontally. The height to which the mixing takes place is called the *mixing height*. A second factor which influences plumes from chimneys is the initial rise of the plume. This can be because the gases emitted from the chimney have a significant vertical speed. It can also be due to the buoyant rise of hot gases.

Write an account of why mixing heights occur and how the effect can be included in simple plume models such as Gaussian models. Discuss also how the effects of buoyant plume rise can be included in models. Your account should be about 1200 words in length (roughly 4 pages) and should take about 6 hours to prepare.

(b) Numerical Solution of the Advection-Diffusion Equation

If we neglect the effects of vertical diffusion, then the dominant processes affecting the dispersion of a pollutant from an isolated source are horizontal diffusion in the directions along and perpendicular to the wind (the x and y directions) and horizontal advection in the downwind direction (the x direction). This may be modelled by the advection-diffusion equation for the concentration $C(x, y, t)$:

$$\frac{\partial C}{\partial t} + U\frac{\partial C}{\partial x} = \frac{\partial}{\partial x}\left(\varepsilon\frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(\varepsilon\frac{\partial C}{\partial y}\right)$$

where U is the wind speed and ε is the horizontal diffusivity. Suppose that the wind speed has a constant value of 10 ms^{-1}. Suppose also that the diffusivity is constant and equal to 20 $\mathrm{m}^2\mathrm{s}^{-1}$. An industrial accident results in an initial cloud of pollutant within a circular region of radius 200 m. Within this the concentration of the pollutant is 1 kgm^{-3}. By means of a numerical solution of the advection-diffusion equation, make predictions of the concentration of pollutant at various times during the next 3 minutes. In choosing your numerical schemes, pay attention to questions of stability, time step restriction, accuracy and whether or not negative values of the concentration should be allowed. Write a short account of your work, describing the numerical scheme which you used and why you chose it. Show contours of concentration at various times and include a copy of your program. Discuss any problems with or limitations of the numerical scheme which you experienced. Your report should be about 3 pages in length, excluding figures. This assignment should take you about 6 hours to complete.