Ocean 420 Physical Processes in the Ocean
Project 1: Hydrostatic Balance, Advection and Diffusion
Due: Thursday, January 18, 2007

To get started

1. Login
    a. Username: Ocean Class (click on the icon)
    b. Password: *ocwaves*
2. Start up MATLAB
3. At the MATLAB prompt, type: *cd c:\classes\ocean420* to change to the Ocean 420 directory
4. Type: *ocean420* to begin running program – you will see a small window pop up with Ocean 420 in the title bar, from here you can choose a demonstration.

1. Hydrostatic Balance

Choose the *Hydrostatic Balance* demonstration from the menu. We will examine the idea that the pressure is determined by the weight of the water above it.

a) Set all of the levels on one of the columns to the lowest possible density. Click the *Calculate Pressure* button. What is the pressure at the bottom?
b) Set all of the densities on one of the columns to the highest possible density and find their pressures. What is the pressure at the bottom? A common approximation in oceanography is that one decibar of pressure is about equal to one meter of water. In this case, how many meters off would you be and in which direction?
c) Experiment with the densities and find two different stable profiles that have the same bottom pressure. Record the densities in all levels for both of them.
d) Given the following two profiles, calculate the pressure gradient between them (at each level) if they are 100 kilometers apart.

1023 kg/m^3	1023.5 kg/m^3
1023.5 kg/m^3	1025 kg/m^3
1024 kg/m^3	1027 kg/m^3
1025.5 kg/m^3	1027.5 kg/m^3
1027 kg/m^3	1028 kg/m^3

e) Click on the *Perturbation* radio button. This shows the densities as a perturbation from the standard value of 1025 kg/m^3. Input the two profiles in d) by subtracting 1025 kg/m^3 from each of the values. Now again calculate the pressure gradient at each level assuming 100 kilometer separation. How are these different from the answers to d)?
f) For the pressure gradients that you calculated in d), calculate the size of the current at each level that would result after one day of the pressure gradient being applied.

2. Advection

In this exercise we will examine the effects of advection. Go to the *Advection-Diffusion* exercises, and choose *Simple Advection*.

a) Initially set the velocity to be uniform across the channel with speed 2.0. Describe how the movement of the particles evolves. Does the distance between particles change over time?
b) The initial set up has a velocity that is linearly sheared across the channel. Examine the particle movement over time. How does the distance between particles change over time? Does the change in distance depend on location?
c) Now try a velocity profile with a large velocity in the middle of the channel, and smaller velocities on the edges. What happens to the line of particles over time?

3. Diffusion

Now choose the *Simple Diffusion* exercise. In this case, we have as an initial condition a uniform temperature fluid. At $t=0$, the temperature at the surface immediately rises. Over time, the heat diffuses into the interior.

a) Do five simulations of the temperature field using values of diffusivity from 1 through 5. Record the time when the temperature at depth 6 reaches 1 unit. Graph this as a function of the diffusion coefficient. What is the relationship between time and the diffusivity?
b) Compare the traces for diffusivities 1 and 5. When does the 5-diffusivity run look like the time 50 trace of the 1-diffusivity run? Use dimensional analysis to explain why this is so. (Remember that the units of the diffusivity are length squared per second).

4. Advection and Diffusion

Now choose the *2-D Diffusion-Advection* exercise. In this case, you have three things you can vary: 1) Where the initial patch of tracer is located (in the fast Gulf Stream or in the slow interior flow), 2) whether the diffusivity is small or large and 3) whether you want a simulation with advection only, diffusion only, or advection with diffusion.

a) Examine the simulations with advection only. For which simulation (fast or slow flow) does the tracer spread out more?
b) Which velocity profile from part 2 does the tracer most resemble for the fast flow?
c) Now try with diffusion only in the Gulf Stream and interior regions. Try both large and small values of diffusivity. Does the tracer spread out more or less as compared to the simulations in part (a)?
d) Imagine that an oil spill has occurred in the Gulf Stream and you are consulted to determine whether the spill will reach Newfoundland. You perform simulations with both large and small diffusivities. Under what conditions will the oil spill reach Newfoundland?
e) In the slow current region, do five simulations, one with advection only, two with diffusion only for both values of diffusion, and two with advection and diffusion with both values of diffusivity. Record the time that the tracer first crosses 30°N. For which simulation does this happen fastest and why?

5. Getting quantitative with advection and conservation (this questions can be done at home)

We are interested in the biological activity in a region of the North Pacific.

a. We have measured the oxygen concentration in the water on a float that moves with the fluid at 100 m depth. We observe oxygen concentration starts at a values of 4 ml/liter and decreases by over the course of 10 days to 2 ml/liter and that the float moves a distance of 50 km. If we assume that there has been no discernable mixing over the 10 days, what would be the oxygen respiration rate?

b. Next we measure oxygen at two fixed moorings that have sensors at 100 m depth. The oxygen levels at the beginning of the experiment are 7 ml/liter at 40N and 140W and 3 ml/liter at 39N and 140W. We also measure a southward current of 5 cm/s. After 10 days, we measure an oxygen concentration of 2 ml/l at the southern mooring. Estimate the respiration rate (ml/l/day) for the southern mooring.