ENGS-151 – Spring 2009
ENVIRONMENTAL FLUID MECHANICS

HOMEWORK #1

Assigned: Thursday 2 April 2009
Due: 10 a.m., Thursday 9 April 2009

1. (10 points) (Problem 1-4 of book) The Fly River Estuary in Papua New Guinea has an average depth of 6 m and an intermittent tidal flow of 1.2 m/s. From river to ocean, the salinity varies from 0 to 30 ppt (ppt = parts per thousand). Knowing that the water density ρ varies with salinity according to

$$\rho = (1000 \text{ kg/m}^3)[\ 1 + 7.6 \times 10^{-4}\ S],$$

where S is the salinity expressed in ppt, determine whether density differences induced by the salinity gradient are dynamically significant.

Also, do you expect the tidal flow to be turbulent? [Water viscosity is 1.0×10^{-3} kg/(m.s).]

2. (10 points) (Problem 1-7 of book) In first approximation, the depth-average velocity in a river is given by

$$U = C\sqrt{gHS},$$

where C is called the Chézy coefficient, g is the gravitational acceleration, H the local water depth, and S the bottom slope. A default value for C is $C = 18$. If the critical value of the Reynolds number for the onset of turbulence is $Re = 5 \times 10^5$ and if the bottom slope is 1 m per kilometer, what are the minimum water depth and velocity that will cause the river to be turbulent? Are these values realistic? What can you conclude about the level of turbulence if the water depth is 70 cm?

3. (10 points) (Problem 1-8 of book) From the weather chart in today’s newspaper or internet site of your choice, identify the horizontal extent of a major atmospheric feature at mid-latitudes and find the associated wind speed. From these length and velocity scales, determine a time scale. Then, knowing that atmospheric motions are affected significantly by the rotation of the earth over half a day’s time (12 hours), what can you conclude about its effect in this case? Append to your answer a copy of the weather chart that you are using. [*Hint*: When converting latitudinal and longitudinal differences on a map into kilometers, use the earth’s radius, 6371 km.]

4. (10 points) (Problem 2-1 of book) A dissolved mineral enters a 2.3×10^5 m^3 lake by a stream carrying a concentration averaging 6.8 g/m^3. The annual flow of this stream into the lake is estimated at 9.2×10^4 m^3, but evaporation over the 4.4×10^4 m^2 surface of the lake reduces the outflow into the continuation of the stream past the lake to 8.3×10^4 m^3 per year. The outflow concentration of the dissolved mineral is 7.0 g/m^3. What is the rate of evaporation from the surface (in centimeters of water per year)? And, is there a source or sink of this mineral inside the lake? What is the rate of this source or sink (in grams per day)?

5. (10 points) (Problem 2-6 of book) The Rhine River at the level of Karlsruhe, Germany, has a nearly rectangular channel that is 190 m wide. During an episode of relatively high flow, the water depth was measured at 4.2 m and the volumetric flow estimated at 1370 m^3/s. If topographic maps indicate that the downstream channel slope is 6×10^{-4}, estimate the values of the frictional stress (in N/m^2) and of the drag coefficient.