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METR 3113 – Atmospheric Dynamics I
Fall 2016

Problem Set #4

Distributed Wednesday, 3 October 2016
Due Friday, 14 October 2016

INSTRUCTIONS: For each of the problems below, apply all 6 steps in the problem-solving handout. Pay close attention to neatness, and describe your work at each step of the solution process.

1. Divergence of the Geostrophic Wind. Show that the geostrophic wind in vector form, assuming constant density and a constant Coriolis parameter, is non-divergent. Comment on this result and note what would happen if the entire atmosphere were perfectly geostrophic.

$$\vec{V}_g = \frac{1}{\rho f}\hat{k} \times \nabla p$$

2. Mass Continuity. Consider a 1000 cubic meter fixed volume of air (you can assume the shape of a cube 10 m on a side) that has ends open only in the x-direction. If the density at the open ends of the volume is 1.2 kg m^{-3} and the velocity decreases toward the east across the volume at a rate of 10 meters per second per meter, determine the density in the volume one hour later if the initial density at the center is 1 kg m^{-3}.

3. Divergence and Vorticity in Simple Flows. For each of the horizontal flows listed below, perform the following, assuming a is a positive constant: (a) Construct a simple graph of the flow (sketching by hand is fine); (b) Compute the vertical vorticity; (c) Computer the horizontal divergence; (d) Comment on the results.

$(i)\ u(x,y) = ax;\ v(x,y) = ay$
$(ii)\ u(x,y) = ay;\ v(x,y) = ax$
$(iii)\ u(x,y) = -ay;\ v(x,y) = ax$
$(iv)\ u(x,y) = ax;\ v(x,y) = -ay$

4. Gravity and the Centrifugal Force. Calculate the altitude at which an artificial satellite orbiting in the equatorial plane can be a synchronous satellite, i.e., remaining above the same spot on the surface of Earth.

5. Pressure Gradient Force and Gravity. The hydrostatic equation represents a balance (in the vertical) between the pressure gradient force and the acceleration due to gravity. Demonstrate this for yourself by computing the pressure gradient force between sea level and the tropopause for the US Standard Atmosphere (look at a thermodynamic diagram).

6. Pressure Gradient Force and Gravity. Suppose now the hydrostatic balance applies in the horizontal. For a typical synoptic-scale weather system, use the difference in pressure between the center of the low and a nearby high, and the average distance between them, to compute the "horizontal gravity" needed to achieve hydrostatic balance. Comment on the result compared to problem 5.