ATM 240 – Fall 2016

Problem set #4 32 pts Due: 27 October 2016

1. **Improbable velocities from conservation of M.**

a. (2 pts) Find M at the starting latitude of 10N if u=0 there.

b. (6 pts) Conserving M, calculate u at these latitudes: 20, 30, 40, 50, 60 N.

2. **Arcing path from latitudinal motion.** At the start of the course, an imaginary circulation which we labelled as a Hadley cell was drawn whereby the upper level circulation included westerly as well as poleward components. This problem is intended to examine what orientation to draw those circulations. Consider a parcel that moves from 10 N to 30 N with a constant meridional component of velocity that equals 2 m/s. Assume that friction is negligible. The parcel is initially at longitude 0 degrees and has $u=U_0$ zonal velocity.

a. (4 pts) Write down expressions relating meridional (y) and zonal (x) distance to longitude (λ) and latitude (φ). From those formulate definitions of v (northward) and u (eastward) velocity using λ and φ.

b. (8 pts) Derive the general formula for radians of longitude travelled when proceeding from latitude φ_S to latitude φ_N The formula should not contain any unsolved integrals. *Hint: use part a to convert between radians and distance and between time and space.*

c. (2 pts) Use your formula to find the ending longitude when the parcel reaches φ_N = 30 N. Let the initial conditions be u=0 at 0 degrees longitude and φ_S = 10 N.

3. **Magnitudes of surface heat fluxes**. Assume the surface latent heat flux is LHF=78 W/m^2 and the surface sensible heat flux is SHF=23 W/m^2. Note that the heating rate $Q = C_P\, dT/dt$ and has units W/kg.

a. (3 pts) Let the SHF heat a boundary layer that is 100 mb thick. Find how rapidly this layer is being heated, expressed in K/day. Hints: P is a force/unit area. Express the heating rate as W/kg then express that result as W/m^3.

b. (4 pts) Find the rate that the LHF is moistening a 1km deep boundary layer. Hint, your answer should be expressed as a local change of mixing ratio (w) where w has units g/kg. Also, let the latent heat of vaporization, L = 2.4x10^6 J/kg. Assume that density is approximated by a scale height H=8km as: $\rho(z) = 1.25\ \exp(-z/H)$ kg/m^3.

c. (3 pts) Express the LHF in terms of an evaporation rate, E, where E has units of mm of liquid water per day.

NOTE: all homework is to be done by you as an INDIVIDUAL: no 'group' efforts, please. For written answers, please use a word processor, so that penmanship is not an issue. Equations and derivations can be *neatly* hand-written. Full credit requires proper units be included. Any plot must be completely and unambiguously labeled, including title and axes. Show ALL math steps.