Problem Set 2

ATM 622: General Circulation of the Atmosphere
October 7, 2019
DUE: October 23, 2019

1) For an ideal gas in hydrostatic balance, show that:

$$\langle \Phi + I \rangle = \langle S \rangle \tag{1}$$

where $\langle\rangle = \int \rho dz$ is the mass weighted vertical integral, $\Phi = gz$, $I = c_v T$, and $S = c_p T$. Use (1) to explain why $\epsilon = S + \Phi + L + K$ is not the actual total energy.

2) Read Trenberth, K. and D. Stepaniak, 2003: Seamless Poleward Atmospheric Energy Transports and Implications for the Hadley Circulation. *J. Climate*, **16**, 3706-3722. (`http://journals.ametsoc.org/doi/abs/10.1175/1520-0442%282003%29016%3C3706%3ASPAETA%3E2.0.CO%3B2`)

a) In the annual mean, the transports of enthalpy (sensible and latent heat) in the tropics are toward the equator, and the transport of potential energy is toward the poles. Explain how this transport fits in with the observed surface enthalpy fluxes (from your observed circulation handout) and the conversion of enthalpy to potential energy in the ITCZ.

b) Figure 4 in Trenberth and Stepaniak (2003) shows the annual mean divergent energy transport. The stationary component consists of both the mean meridional and stationary eddy components, while the transient component consists of the transient eddy component. How does the latitudinal distribution of stationary and transient poleward flux of energy make for a "seamless" poleward energy transport? Use your knowledge of the observed circulation to explain why the local maxima/minima in the stationary and transient energy transport divergence are located where they are (i.e., what phenomena are they tied to)?

3) Consider the flow of energy in the rotating tank baroclinic eddies experiment from the previous lab.

a) Explain why a tank of water in solid body rotation with no temperature gradient is a reference state. Draw a sketch and explain how introducing ice in the inner cylinder causes the available potential energy to increase.

b) Diagram the flow of energy between mean available potential energy, eddy available potential energy, mean kinetic energy, and eddy kinetic energy. Qualitatively explain the conversions between the different energies. Identify key external sources and/or sinks of each energy, if they exist at all for a given energy.