Climate & Sustainability

PHYS 189 Fall 2017

Problem Assignment # 6

due 10-23-17

1. What is a "gravity wave" and how does one happen in the atmosphere?

2. (a) Define in words and equations (where applicable):
   i. vapor pressure
   ii. saturation vapor pressure
   iii. specific humidity
   iv. saturation specific humidity
   v. relative humidity

   (b) Which of the above actually measures moisture content?

   (c) Which of the above do *not* measure moisture? What variables do they depend on?

3. The first law of thermodynamics

   (a) Write down the first law of thermodynamics and define all terms in the equation.

   (b) What is an *adiabatic* process? How does the first law of thermodynamics simplify for an adiabatic process?

   (c) How does this apply to cloud development?

4. (a) How do we know when an air parcel is saturated? (You may answer in terms of variables from the previous problem).

   (b) Describe the most common method that an air parcel can become saturated.

   (c) What do we mean when we say "warm air can 'hold' more moisture than cool air"? It may help to consult figure 3.4 in your book.

5. The *dew point temperature,* T_d, is the temperature at which an ascending parcel becomes saturated. To answer the following questions, go to the online tutorial: `http://www.physics.nmt.edu/~sessions/phys189/ch05/ch05_Tutorials/Atmospheric_Moisture_and_Condensation/Measures_of_Atmospheric_Moisture.html`.

   (a) The curve represents the *saturation vapor pressure* (similar to figure 3.4 in your book), the blue line is the *actual vapor pressure*. What does the green line represent?

   (b) In the default conditions (temperature is 40°C, vapor pressure is 40 mb), what is the dew point temperature? What is the relative humidity? Is the system saturated?

   (c) What are two ways to saturate the system in this figure?

   (d) Decrease the temperature to 32°C. What is the dew point temperature? What is the relative humidity? Explain why one increased but the other stayed the same.

   (e) Increase the temperature back to 40°C. Increase the vapor pressure to 60 mb. What is the dew point temperature? What is the relative humidity? Explain your observations.

   (f) When the temperature is 40°C, what is the maximum you can increase the vapor pressure? Why does it stop at this value? What is the relative humidity at this value? What is the dew point?

(g) Does dew point temperature measure temperature or moisture?

6. Refer to Figure 3.5 to answer the following questions.

   (a) Approximately what altitude is the minimum in moist static energy?

   (b) Why is there a minimum in the moist static energy in the tropical mid-troposphere?

   (c) The level of free convection (LFC) and level of neutral buoyancy (LNB) are labelled in the figure. How are these determined?

7. The dry adiabatic lapse rate, $\Gamma_d \approx 1$ K/100 m, and the moist (or saturated) adiabatic lapse rate, Γ_m depends on moisture content, but is approximated by $\Gamma_m \approx 0.5$ K/100 m in the lower troposphere.

   (a) If a parcel has 50% relative humidity, what rate will it cool as it rises?

   (b) If a parcel has 100% relative humidity, what rate will it cool as it rises?

   (c) Why is $\Gamma_d > \Gamma_m$?

   (d) Γ is the *environmental lapse rate*, which measures the actual decrease in temperature with altitude. If $\Gamma_d > \Gamma > \Gamma_m$, the environment is *conditionally unstable*. What does this mean? In other words, if a parcel is lifted adiabatically, how fast will it cool?

8. Suppose an unsaturated air parcel starts at sea level with a temperature of 10° C and rises to the lifting condensation level at 1 km. The parcel continues to rise at the saturated adiabatic lapse rate of 0.5° C/100 m to a mountain peak at an elevation of 4 km. What is the temperature of the parcel at the peak?

9. Winds warmed by compression that descend the eastern slopes of the Rocky Mountains are known as chinooks. At a mountain peak of 4 km, a saturated parcel is -15° C. The parcel precipitates out excess moisture so that it descends the eastern slope back to sea level as an unsaturated parcel. Calculate the temperature of the parcel at sea level.

10. (a) What is CAPE?

    (b) What is CIN?

    (c) How do these determine how convection evolves?

11. Why do cumulus updrafts occupy only a small fraction of the available area for convection?

12. What is the ITCZ?

13. The figure below shows profiles of dry static energy (blue, left curve), moist static energy (green, middle curve), and saturated moist static energy (red, right curve).

    (a) Write down the equations for moist static energy and saturated moist static energy. Explain briefly what each term in the equations are.

    (b) Is **dry** static energy conserved in **unsaturated** air parcels which are ascending adiabatically? (Hint, water is *not* condensing.)

    (c) Is **dry** static energy conserved in **saturated** air parcels which are ascending adiabatically? (Hint: water is condensing.)

    (d) Is **moist** static energy conserved in **unsaturated** air parcels which are ascending adiabatically? (Hint, water is *not* condensing.)

(e) Is **moist** static energy conserved in **saturated** air parcels which are ascending adiabatically? (Hint: water is condensing.)

(f) In the figure below, assume an air parcel lifted from the surface has constant moist static energy, draw a line corresponding the the moist static energy of the parce.

(g) In the figure below, what is the approximate lifting condensation level?

(h) In the figure below, what is the approximate level of neutral buoyancy?

(i) In the figure below, shade **and label** the region corresponding to CAPE.

(j) In the figure below, shade in different color or with a different pattern **and label** the region corresponding to convective inhibition (CIN).

(k) Based on this figure, do you expect to observe convection in the region?

(l) Suppose the moist static energy at the surface is 340000 J/kg, how would the CAPE and CIN compare to the situation shown? Are you more or less likely to get convection? Explain.