ATM 240 – Fall 2019

Problem set #7 30 pts Due: 19 November 2019

1. **Hadley cell as a Carnot cycle** during DJF. The air in circulation has these 4 rectangular domains:

i). 15S – 5S from 1000 → 200 mb ii). 5S → 25N from 500 - 200 mb.

iii). 35N - 25N from 200 → 1000mb iv). 25N → 5S from 700 - 1000 mb

a. (5 pts) Calculate the total mass of air in circulation. (Sum the masses in the 4 rectangular domains.)

b. (6 pts) Next track a representative parcel from this path. **Step 1**: from 1000mb @ 30N (T=286K) to 1000mb @ 10S (T=298K); **Step 2**: from 1000mb to 400mb @ 10S (within a thunderstorm whose base is at 950 mb). **Step 3**: the parcel travels northward at speed V=1.3 m/s until reaching 30N (whereupon v=0) while cooling at rate 1 K/da. **Step 4**: continued cooling at a rate of 1 K/da until reaching starting point. Calculate and show the following:

i) find the potential temperature at top of the thunderstorm by consulting the chart used in part c

ii) estimate the time for the parcel to reach 30N

iii) using the cooling rate estimate the potential temperature at time parcel reaches 30N

iv) from figure 3.15a, estimate the P elevation of that potential temperature

v) how long does it take to travel the entire 3rd step?

vi) how long does it take to travel the entire 4th step?

c. (4 pts) Using information given in part b, plot the COMPLETE path followed by the representative parcel on the provided Skew-T ln-P chart. (Hint: The path should enclose an area made of 4 straight-line segments and 1 curving segment.) Estimate the area of this curve.

d. (2 pts) Assume that the time rising (beneath the LCL plus within the thunderstorm) totals 33 1/3 minutes and that the first leg is covered with an average speed of 1.3 m/s. Using your answer to part b, how long does it take the parcel to complete one circuit?

e. (2 pts) Using the fact that 1 cm^2 = 0.168 J/gm and your answers to parts a, c, and d to find the rate of energy release in units of W.

f. (3 pts) Find the horizontal area A (using the furthest limits) of the Hadley cell. Divide your answer in part e by A to obtain the energy released in W/m^2. How does it compare to the incoming and absorbed solar radiation?

2. **Calculate spectra of precipitation rate**, P on 20190109 at two latitude bands: 3-5 South and 39-41 North. The P data are accessible from the class website. To avoid complex arithmetic, find the Fourier coefficients for both the cosine a(k), and sine b(k), series then combine them to obtain c(k) = sqrt($a^2(k) + b^2(k)$).

Let the x range be: 0 to 2π-dx where dx=2π/N, where N=192 for these data Use the summation formulas:

$$a(k) = \frac{1}{N}\sum_{j=0}^{N} f(x_j)\cos(kx_j) \text{.....and.....} b(k) = \frac{1}{N}\sum_{j=0}^{N} f(x_j)\sin(kx_j)$$

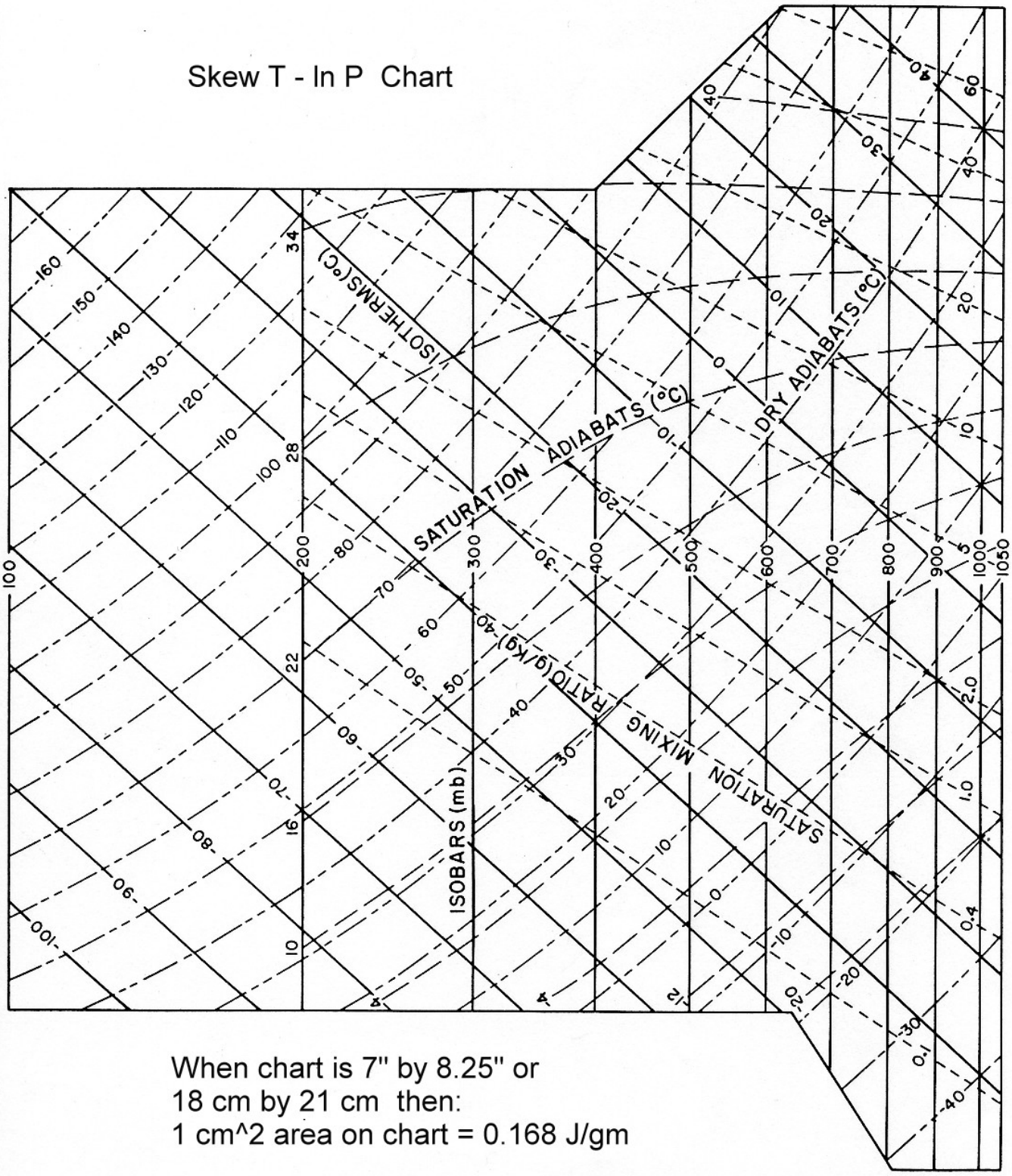
a. (2 pts) Plot the distributions of P at the two latitudes on the same chart. Ensure that your chart has the proper labels. Plot the data as mm/day.

b. (6 pts) Find the spectrum (c(k)) for P at both latitudes. In each case let k=0 through 25 (k is an integer). Then, plot both resultant spectra from k=1 to 25 on the same chart. (A bar chart works best.)

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.

Any plot must be completely and unambiguously labeled, including title and axes.

Skew T - ln P Chart



When chart is 7" by 8.25" or
18 cm by 21 cm then:
1 cm^2 area on chart = 0.168 J/gm