NATS 1780 A (Summer 2020): Assignment 2 (Version 1.0) - July 6, 2020

Due: July 25, 2020 (via Moodle)

(Late Penalty: 25% per day - including weekends; 100% deduction after solutions are posted.)

Instructions:

- You are expected to provide answers for *every* question. You are encouraged to show all of your work so that marks can be awarded for partially correct answers.
- Although you are encouraged to collaborate with your classmates, each of you is expected to submit a separate and distinct assignment.
- Use $SVP\ (T) = 6.112\ e^{[17.62\ T\ /\ (243.12\ +\ T)]}$ where T is the environmental or dew-point temperature in ^{o}C; SVP is in hPa. Note that there is a SVP-from-T calculator available via Moodle.
- Use $T\ (SVP) = (243.12/17.62) * \{\ 17.62 * ln\ [\ SVP(T)\ /\ 6.112\ ]\ \}\ /\ \{\ 17.62\ -\ ln\ [\ SVP(T)\ /\ 6.112\ ]\ \}$ to retrieve the T (^{o}C) from the SVP. Note that there is a T-from-SVP calculator available via Moodle.

1. List the necessary and sufficient conditions for the formation of clouds. [2 marks]
2. The necessary condition can be satisfied through one of four cloud-producing mechanisms. State the mechanisms. What do each of these mechanisms have in common. [6 marks]
3. With respect to Figure 1, and assuming the sufficient condition has been met:
    a. Apply the necessary condition identified in Question 1 to determine the base of the cloud. [1 mark]
    b. By applying this necessary condition a second time, state the thickness of the cloud. Enter this thickness as an altitude range in the first column of the table below. [2 marks]
    c. Based on Question 3(b) above, enter the thickness of the cloud-free layer (above the cloud) as an altitude range in the first column of the table below. [1 mark]
4. Within the cloud identified in Question 3, and assuming that precipitation is occurring:
    a. Which precipitation mechanism is most likely active? Add this to the table below in the “Process(es)” column corresponding to the “Cloud layer”. [1 mark]
    b. What is the state of hydrometeors that emerge from the base of the cloud? Add this to the table below in the “Precipitation Type” column corresponding to the layer below the “Cloud layer”. [1 mark]
    c. Provide a sketch that captures the changes of state in H_2O. Include the six processes responsible for these state changes, as well as the changes in energy. [10 marks]
    d. Distinguish between state and phase. Which state of H_2O is known to have multiple phases? [3 marks]

5. The Figure 1 profile for T_{ENV} intersects *twice* with the 0 ℃ isotherm.
    a. Provide the altitudes corresponding to these two intersections. Add them to the table below. [2 marks]
    b. For the layer between these points of intersection:
        i. State the active process from your Question 4(c) sketch. Add this to the table below. [1 mark]
        ii. Is the process identified in Question 5(b)(i) an endothermic or exothermic one? [1 mark]
        iii. Inspired by the process identified in Question 5(b)(i), provide an appropriate name for this layer, and enter it into the table below. [1 mark]
        iv. Add the altitude range for this layer to the table below. [1 mark]
        v. What is the state of hydrometeors in this layer? Add this to the table below in the “Precipitation Type” column. [1 mark]
    c. For the lowermost layer - i.e., the layer below the lower of the two points of intersection:
        i. State the active process from your Question 4(c) sketch. Add this to the table below. [1 mark]
        ii. Is the process identified in Question 5(c)(i) an endothermic or exothermic one? [1 mark]
        iii. Inspired by the process identified in Question 5(c)(i), provide an appropriate name for this layer, and enter it into the table below. [1 mark]
        iv. Add the altitude range for this layer to the table below. [1 mark]
        v. What is the state of hydrometeors in this layer? Add this to the table below in the “Precipitation Type” column. [1 mark]
    d. For the layer below cloud base, but above the second point of intersection:
        i. State the active process from your Question 4(c) sketch. Add this to the table below. [1 mark]
        ii. Is the process identified in Question 5(d)(i) an endothermic or exothermic one? [1 mark]
        iii. Inspired by the process identified in Question 5(d)(i), provide an appropriate name for this layer, and enter it into the table below. [1 mark]
        iv. Add the altitude range for this layer to the table below. [1 mark]
6. Distinguish between DALR and MALR. Complete the final column of the table below by indicating whether DALR or MALR applies. [7 marks]
7. Distinguish between saturation and precipitation. [2 marks]
8. Determine the slope of T_{ENV} versus altitude in ℃/km for Figure 1 above 5.0 km. [3 marks]
9. *Extrapolate* the slope determined in Question 1 to 0 km. State the corresponding temperature in ℃. [3 marks]
10. Based upon values for T_{ENV} and T_{DEW} obtained from Figure 1, verify that the RH is 18.4% at an altitude of 2.0 km through calculations. [4 marks]
11. Regarding the region below the cloud in Figure 1:
    a. State the total thickness of this region in km. [1 mark]

b. State the thickness of the layer in between the two intersection points with the 0 ℃ isotherm - i.e., then the thickness corresponding to the range determined in answer Question 5(b)(iv). [1 mark]
c. State the sum of the thicknesses of the lowest layer (the thickness corresponding to the range determined in answer to Question 5(c)(iv)) plus the layer below cloud base, but above the second point of intersection (the thickness corresponding to the range determined in answer to Question 5(d)(iv)). [1 mark]
d. Express the thickness of the layer in between the two intersection points with the 0 ℃ isotherm (i.e., your answer for Question 11(b) above) as a percentage of the total thickness of the region below the base of the cloud (i.e., your answer for Question 11(a) above). [2 marks]
e. Express the sum deduced in Question 11(c) as a percentage of the total thickness of the region below the base of the cloud (i.e., your answer for Question 11(a) above). [2 marks]
f. Assuming that a hydrometeor that exits the cloud falls at a constant rate, as it makes its way to the ground, provide relative estimates for the time spent in the layers based upon the percentages deduced in questions 11(d) versus 11(e). Note that these relative estimates can be expressed as percentages of time. [2 marks]

12. Perform stability analyses for Figure 1 as follows:
    a. For the temperature profile provided via Figure 1 as is. [11 marks]
    b. For the temperature profile implied by the *extrapolated* slope deduced in Question 9. [11 marks]

    In *each* case, you should compare the temperature of the parcel with that of the environment. Then state the stability and motion of the parcel.
13. Illustrate a stable, unstable or neutrally stable atmosphere through the use of a photograph that you have taken. Include with your submission essential logistics and weather conditions corresponding to the photograph. Be sure to indicate which of the three stability states is captured through your photograph. [4 marks]
14. Based on the results of your stability analysis (your answers to 12(a) and 12(b) above), would you expect the cloud tops (identified in 3(b)) to rise/grow, fall/decay or remain the same? [4 marks]
15. Based on your answers for Question 14 above, which type(s) of cloud(s) would you expect to result. Explain. [4 marks]

Total Marks: 105

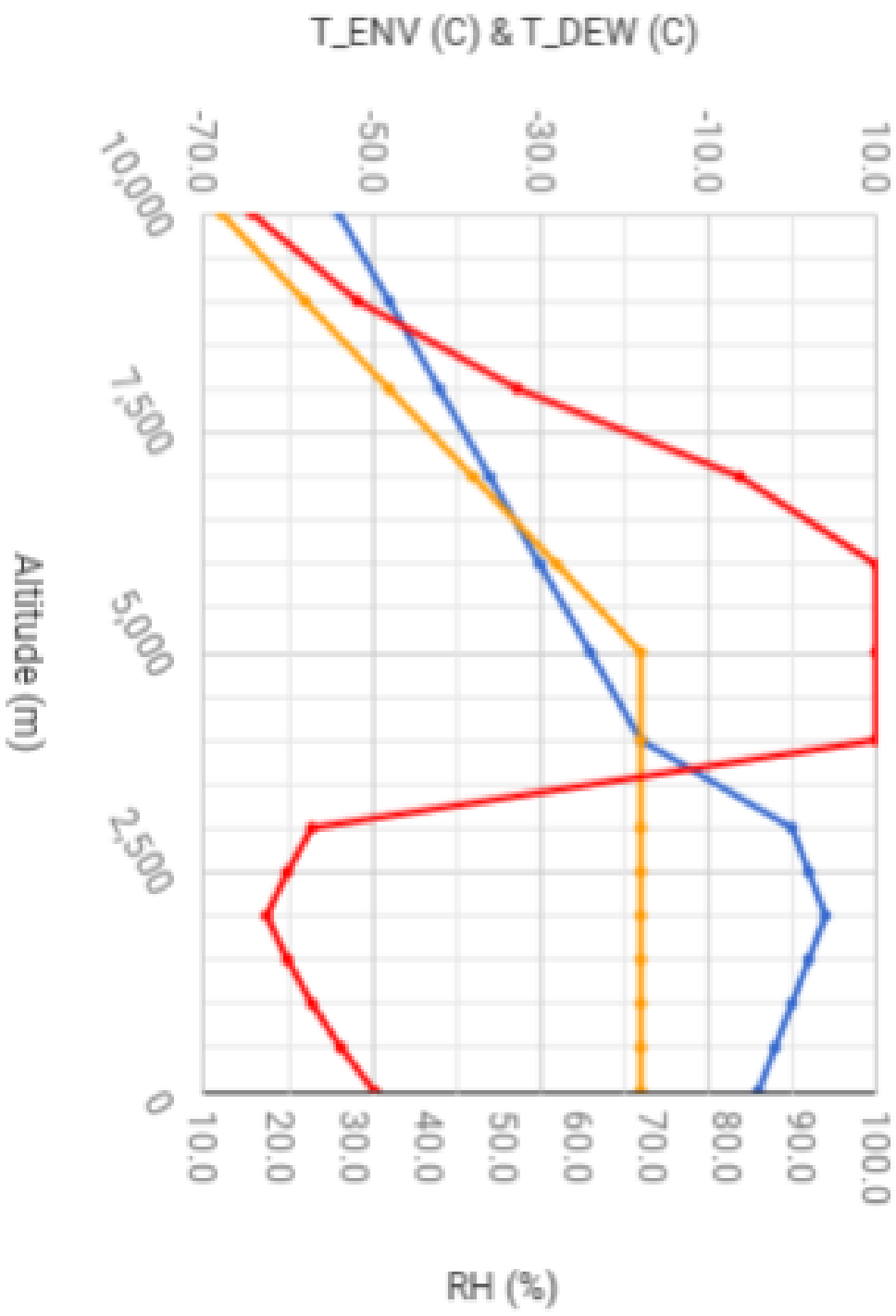

Figure 1. Environmental temperature (T_{ENV} in blue), dew point (T_{DEW} in orange) and RH (in red) as a function of altitude.

Altitude (m)	T_DEW (C)	T_ENV (C)	RH (%)
0	-18.0	-4.0	32.8
500	-18.0	-2.0	28.3
1,000	-18.0	0.0	24.4
1,500	-18.0	2.0	21.2
2,000	-18.0	4.0	18.4
2,500	-18.0	2.0	21.2
3,000	-18.0	0.0	24.4
4,000	-18.0	-18.0	100.0
5,000	-18.0	-24.0	100.0
6,000	-28.0	-30.0	100.0
7,000	-38.0	-36.0	81.7
8,000	-48.0	-42.0	51.9
9,000	-58.0	-48.0	30.5
10,000	-68.0	-54.0	16.4

Figure 2. Raw data corresponding to Figure 1.

Altitude (km)	**Name**	**Process(es)**	**Precipitation Type**	**DALR or MALR?**
Question 3(c)	Cloud-free atmosphere			*Question 6*
Question 3(b)	Cloud layer	*Question 4(a)*		*Question 6*
Question 5(d)(iv)	*Question 5(d)(iii)*	*Question 5(d)(i)*	*Question 4(b)*	*Question 6*
Question 5(a)	0 ℃ isotherm intersection			
Question 5(b)(iv)	*Question 5(b)(iii)*	*Question 5(b)(i)*	*Question 5(b)(v)*	*Question 6*
Question 5(a)	0 ℃ isotherm intersection			
Question 5(c)(iv)	*Question 5(c)(iii)*	*Question 5(c)(i)*	*Question 5(c)(v)*	*Question 6*

Above table to be completed and submitted as part of your assignment.

