San Francisco State University Spring 2018
Department of Earth & Climate Sciences

ERTH 260: Physical Processes in the Atmosphere

Inclass Exercise 8 Key: **Potential Temperature and Potential Density (100 pts)**
Due Wednesday 4 April

Potential temperature is useful in a number of meteorological applications. We've discussed a few of them already in class. But the specific use of potential temperature in understanding density differences will also help you understand the conceptual underpinning to general topic of "instability".

From the stand point of the point at which we find ourselves now in ERTH 260 you can think of instability as referring only to the tendency of air parcels to spontaneously move vertically due to density differences between the air parcel and the surrounding environmental air at the same elevation.

Sometimes students come to this topic with considerable preconceived notions. One common misconception is that spontaneous vertical motions occur when cold air aloft sinks relative to warm air near the surface, which rises. The usual logic is that the cold air is denser and warm air is lighter. In other words, in situations in which air parcels aloft are cold relative to the temperature of the underlying surface air parcel, spontaneous sinking of the cold air would occur, and spontaneous rising of the warm air would occur.

As you will see, this is a misconception. Let's call this preconceived notion "**Misconception #1**".

Consider the scenarios shown by the Skew T/log P chart given as Figure 1. The air parcel at 1000 mb has a temperature of 20C. Three other air parcels are shown as A, B, and C, all located at the 350 mb level. The scenarios consist of the same air parcel temperature at 1000 mb, but three different days on which the air parcel temperatures at 350 mb are either as shown at A, B, or C.

1. Fill in Table 1 with the appropriate temperatures obtained from Fig. 1. **(20 pts)**.

2. According to **Misconception #1** Fill in Table 2 with whether the air parcel at a given level would rise or sink with the letters"R" or "S". **(20 pts)**.

3. Fill in Table 3 with the Potential Temperature (K) of each air parcel for each of the scenarios. **(20 pts)**.

4. Recall that the definition of potential temperature is the temperature (K) an air parcel would have if it were brought dry adiabatically to a pressure

elevation of 1000 mb.

Also recall that the Ideal Gas Law states that at a given pressure warm air is less dense than cold air. Hence, the potential temperatures of air parcels really represent a measure of their relative densities when the air parcels are brought dry adiabatically to 1000 mb, with the higher potential temperatures indicating LOWER potential densities. In reality, spontaneous vertical motions will occur only if the POTENTIAL densities of air parcels are different, with the lower potential density air rising, and the lower potential density air sinking.

Only one of the scenarios shown in Table 3 would have the 350 mb air parcel spontaneously sink paired with the 1000 mb air parcel spontaneously rising. Discuss which and provide an explanation in several complete sentences, contrasting your result here with the results you got from applying Misconception #1 in Question 2. **(20 pts)**

**In Scenario C, the potential temperature of the 350 mb air parcel is indeed colder than the potential temperature of the 1000 mb air parcel. Only this Scenario has potentially denser air overlying potentially less dense air, so that spontaneous vertical motions will occur. Misconception 1misleads the observer into thinking all the Scenarios have denser air overlying lighter air.**

5. One of the indicators of instability (spontaneous vertical motion) is expressed by this simple formula:

$$\frac{\Delta\theta}{\Delta z} < 0 \qquad \text{Condition for Absolute Instability}$$

   a. Write the concept of this expression out in plain English. **(10 pts)**

      **Absolute Instability (spontaneous vertical motions) occur when potential temperature decreases with height (or when the term Δ theta/Δz is negative).**

   b. Is your answer in (4) above consistent with this condition. Explain. **(10 pts)**

**Yes, only in Scenario C was the potential temperature higher on the z-axis less than the potential temperature at the 1000 mb level.**

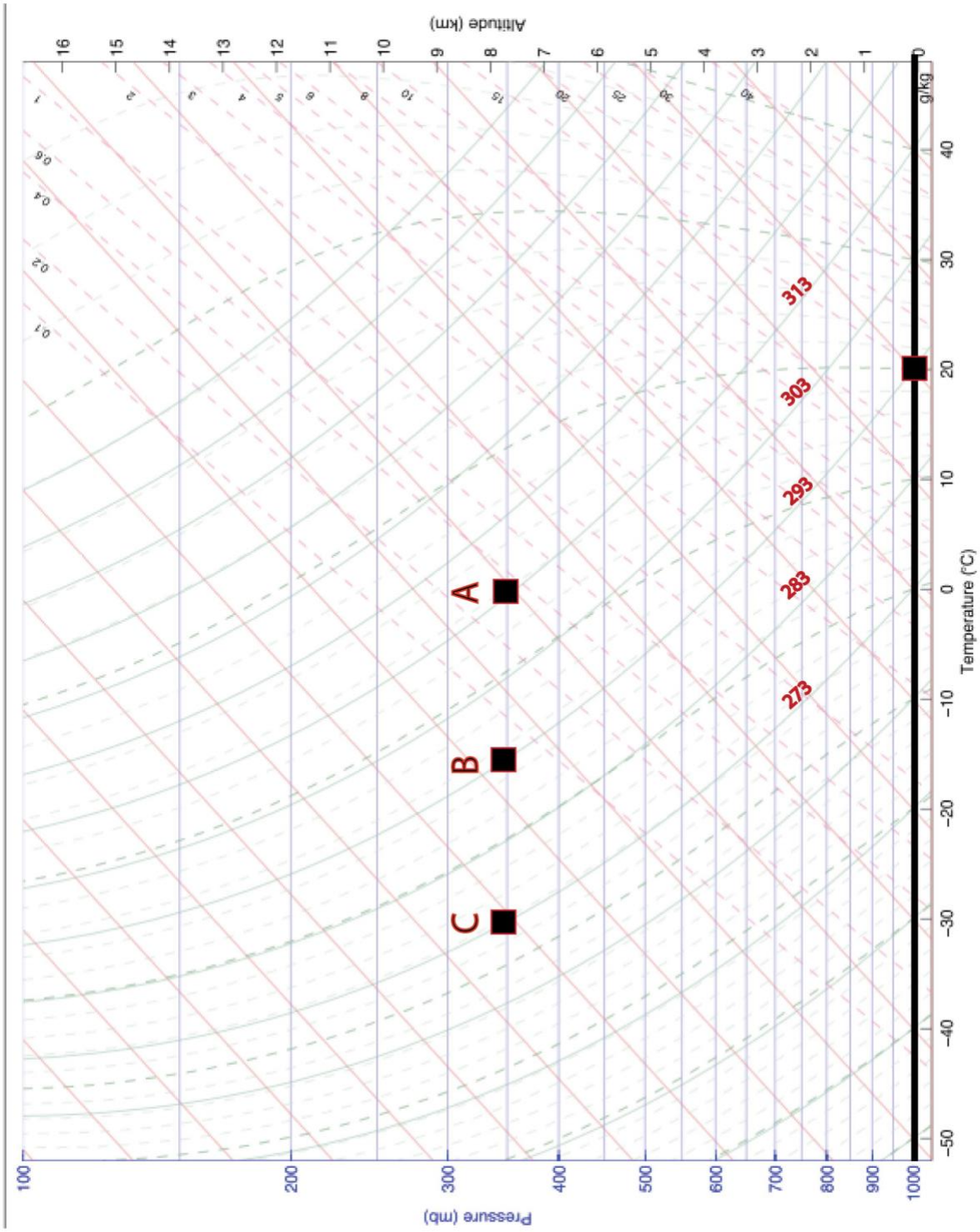
Pressure (mb)
Altitude (km)
Temperature (°C)
g/kg
A
B
C
273
283
293
303
313

Figure 1: Skew T/log P Diagram showing four air parcels.

| Air Parcels (AP) | 1000 mb AP | 350 mb AP A Scenario A | 350 mb AP B Scenario B | 350 mb AP C Scenario C |
|---|---|---|---|---|
| Temperature (C) | 20C | -40C | -57C | -73C |

Table 1: Air Parcel Temperatures (obtained from Fig. 1) for the Air Parcel at the surface and for 350 mb air parcels in three different Scenarios, A, B, and C.

| Air Parcels (AP) | 1000 mb AP | 350 mb AP A Scenario A | 350 mb AP B Scenario B | 350 mb AP C Scenario C |
|---|---|---|---|---|
| Rising/Sinking | R | S | S | S |

Table 2: Deduced spontaneous rising or sinking motion for the Scenarios shown in Table 1, based upon Misconception #1.

| Air Parcels (AP) | 1000 mb AP | 350 mb AP A | 350 mb AP B | 350 mb AP C |
|---|---|---|---|---|
| Potential Temp (K) | 293K | 303K | 293K | 273K |

Table 3: Potential Temperatures (K) for each air parcel in each of the Scenarios, obtained from Fig. 1.