1 Objective

Gain familiarity with temperature and moisture changes associated with adiabatic ascent and descent. Gain insight into the implications of these changes for atmospheric convection. Become acquainted with the physical meaning of potential temperature and equivalent potential temperature.

2 Materials Needed

- Skew T Log P diagram
- One radiosonde sounding in tabular form

3 Introduction

Over short time scales (minutes to hours), parcels of air moving about in the atmospheric exchange little heat with their surroundings. Therefore their response to changes in pressure can be regarded as approximately adiabatic.

If a parcel is unsaturated, then no condensation of water is taking place; in such a case, the temperature tends to stay on a dry adiabat and the dewpoint follows a line of constant saturation mixing ratio \( w_s \). If the parcel continues to rise, eventually the temperature and dewpoint meet and the parcel becomes saturated. The pressure level at which this occurs is called the Lifting Condensation Level, or LCL. The LCL corresponds to the altitude at which a cloud base would be observed for that rising parcel.

If the saturated parcel continues to ascend to higher altitude (lower pressure), condensation occurs. The amount of liquid water that condenses is just enough to keep the parcel almost exactly at saturation. Latent heat release by the condensing water warms the parcel, which means that the parcel does not cool as rapidly with increasing height as it would if it were unsaturated. When condensation is occurring, the parcel will follow a moist adiabat, also known as a saturation adiabat or even pseudoadiabat. Because of the latent heat release, moist adiabats are less sharply sloped to the left than dry adiabats.

A descending parcel that contains condensed cloud water will remain saturated and follow a moist adiabat until all of the condensed water has evaporated. After that, it follows a dry adiabat. Dry adiabats are actually lines of constant potential temperature \( \theta \). The value of \( \theta \) for a given adiabat is the temperature at the point where it intersects the 1000 mb isobar.

A related quantity is the equivalent potential temperature \( \theta_e \), which takes into account the latent heat carried by any water vapor in the parcel. A moist adiabat is a line of constant \( \theta_e \). The value of \( \theta_e \) for the moist adiabat is found by following it up to a high cold altitude where \( w_s \) is as close to zero as possible and then determining its potential temperature \( \theta \) at that point (e.g., by following a dry adiabat back down to 1000 mb).

4 Procedure

1. Plot the temperature and dewpoint from the sounding provided on your Skew-T diagram. Also plot the wind barbs on the right hand side of your chart.

2. On sheet of paper that you will turn in with your answers to this and the following questions, write down the pressures and temperatures associated with the coldest and warmest temperatures
found on your sounding (you may consult the original tabular data for this information). In words, state where these two levels are found (e.g., surface, tropopause, top of a low level inversion near XXX mb, etc.).

3. Use the mathematical formula for potential temperature to calculate the $\theta$ for the above two cases. How do they compare?

4. Determine $\theta$ graphically for the same parcels by following a dry adiabat to the 1000 mb level. Do you get about the same answer as before?

5. In general, temperature tends to decrease with height in the troposphere, with the possible exception of an inversion or two. By examining your plotted sounding and/or the tabular data (which includes a column for $\theta$), determine whether potential temperature generally increases or decreases with height in the atmosphere. More specifically, specify the precise range(s) of pressure over which $\theta$ is constant, decreases, or increases with height in your sounding.

6. Graphically “lift” a parcel from the surface level of your sounding to the highest level you can without running off the chart. Follow a dry adiabat to the LCL and a moist adiabat after that. Then record the following information:

7. The starting temperature, dewpoint, pressure, and mixing ratio $w$ of the parcel.

8. The temperature, dewpoint, pressure, and mixing ratio of the parcel at the LCL.

9. The temperature, dewpoint, pressure, and mixing ratio of the parcel at the 700 mb level.

10. The temperature, dewpoint, pressure, and mixing ratio of the environment at the 700 mb level.

11. Compare the mixing ratio $w$ of the parcel at 700 mb with its starting $w$. By how much did it change? Where did the water vapor go?

12. Find the top of the parcel’s moist adiabat on your chart and follow a dry adiabat back down to the 1000 mb level in order to estimate the equivalent potential temperature $\theta_e$. How does $\theta_e$ compare with the potential temperature $\theta$ you found earlier? What physical process is responsible for the difference? How does your $\theta_e$ compare with the value given in the sounding table?

13. Compare the temperature of the environment at 700 mb item with that of the parcel at the same pressure level. Which is greater, and by how much? Based on your knowledge of the ideal gas law, which has the greater density? If the parcel is “let go”, will it continue rising or will it sink back to a lower altitude?

14. Repeat the above process, but this time for a parcel of environmental air taken from the 700 mb and brought down to the surface. How does its final temperature compare with that of its new surroundings? If let go, will it stay put, rise, or continue to sink?

15. What do your answers to the previous two items tell you about the likelihood of spontaneous exchanges of parcels of air between the surface and the 700 mb level? If a stable environment is one that resists vertical motions of parcels, and an unstable environment is one that encourages vertical motions, which characterization seems to apply here?
16. On your chart, plot a point at a temperature of 10° C and pressure 700 mb. Plot another point at 0° C and 600 mb. Connect the two points with a straight line.

17. Assume that the line segment you just drew is supposed to represent the temperature profile of the environment between those two pressure levels on some particular day. From any convenient location near the middle of the segment (e.g., where it crosses a dry adiabat), consider how a parcel of air displaced vertically, either upward or downward, from that location responds to that displacement. Does its temperature, relative to its surroundings, change in such a way that it would continue moving away from its starting point, or would it tend to return? Consider two cases: (1) the parcel is unsaturated and therefore follows a dry adiabat; (2) the parcel is saturated (and perhaps contains condensed cloud water) and therefore follows a moist adiabat.

18. Based on the above analysis, state whether the temperature profile you drew is (a) stable with respect to both unsaturated and saturated parcels, (b) unstable with respect to both unsaturated and saturated parcels, OR (c) conditionally unstable (i.e., stability depends on whether the parcel is saturated).

19. Based on your analysis, what are the criteria for (a) absolute stability, (b) conditional instability, and (c) absolute instability? That is, how can you tell by looking at the environmental lapse rate at any level whether it is stable or unstable at that level?

20. For the actual sounding you plotted, identify (using the bounding pressure levels) all layers that are (a) absolutely stable, (b) conditionally unstable, and (c) absolutely unstable. Explain why you think absolutely unstable layers are rare in the real atmosphere. Also explain what this has to do with the fact that θ almost always increases with height in the atmosphere.