BASIC CONVECTION I: A Review of Atmospheric Thermodynamics

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The *Learning Objectives* for readers of this technical document are to empower students to:

1. Know why the Skew-T, log P diagram is preferred over the Stuve diagram

2. Describe the dry adiabatic process in terms of potential temperature and entropy

3. Describe the variation of the moist adiabatic lapse rate with respect to pressure and temperature on the Skew-T, log P diagram

4. Differentiate between conditional and convective instabilities

5. Describe the major limitation of using stability indices derived from a sounding when determining the potential for deep moist convection

6. Discuss the difference between synoptic scale and mesoscale systems in the initiation of deep moist convection

7. Explain the preference for using the Convective Available Potential Energy (CAPE) as an indicator of the atmospheric instability rather than the Showalter Index, Total Totals Index, or George's K Index

8. List ways the negative area on a sounding can be eliminated or reduced

Given the CAPE, students will be able to calculate the peak vertical velocities associated with an updraft and downdraft.

Given a sounding, students will be able to recognize and discuss problems with the use of those sounding data to assess the potential for convection.

Given a sounding, surface, and upper level charts, students will be able to forecast changes to the sounding and then discuss the potential for deep moist convection after computing the following thermodynamic variables:

a. Lifted Condensation Level (LCL),
b. Level of Free Convection (LFC),
c. Convective Condensation Level (CCL),
d. Equilibrium Level (EL),
e. Positive and negative areas,
f. Any stability index you desire.

DRY AND MOIST CONVECTION

DEFINITION OF CONVECTION

When operational meteorologists hear the term “convection,” they often think of thunderstorms. Although thunderstorms are a form of convection, in a broader sense, convection refers to the transport of heat (and moisture) by the movement of a fluid. In atmospheric convection, part of the heat transferred is called sensible heat, since it is the heat one might “sense” with a thermometer. If water vapor is in the air, the possibility exists that latent heat will be realized. The heat is called “latent” because one cannot sense it until the water vapor condenses. When water vapor condenses, it releases that heat absorbed when the water was vaporized (the heat of vaporization) into the parcel. Thus movement of the fluid can transfer latent heat as well as sensible heat. Convection is not always made visible by clouds; convection which occurs without cloud formation is called dry convection.

DEFINITION OF INSTABILITY

Instability, in general, describes the reaction of parcels displaced from their original position. If the situation is unstable, the parcel accelerates in the direction of the displacement. If it is stable, the parcel is accelerated in the direction opposite to the displacement. In neutral situations, parcels experience no accelerations.

For our purposes, we are interested in what happens to parcels displaced vertically. Vertical accelerations are described by the third equation of motion. With suitable simplifications, this equation reduces to what we call *simple parcel theory*:

$$\frac{dw}{dt} = -\alpha \frac{\partial p}{\partial z} - g,$$

where ***w*** is the vertical component of motion, ***a*** is the specific volume (inverse density, 1/ρ, where ρ is the density), ***g*** is the acceleration due to gravity, and ***z*** is the height. This relationship shows that vertical accelerations are attributable to imbalances between the vertical pressure gradient and gravity. If there is no acceleration, ***dw/dt*** vanishes and the result is the familiar **hydrostatic equation**.

Under suitable assumptions, it can be shown that this description of parcel theory can be approximated by:

$$\frac{dw}{dt} \approx g \frac{(T' - T)}{T},$$

where ***T*** is the environmental temperature (in °K) and ***T′*** is temperature (°K) of the parcel. This equation states that the vertical acceleration along the path of a rising parcel is related simply to the temperature difference between that parcel and its environment. If the parcel is warmer than its surroundings, the parcel is accelerated upward, while if it is colder, it is accelerated downward. The primary assumption here is that vertical displacement of the parcel causes it to change its temperature (as it rises and expands, or sinks and compresses) along moist or dry adiabats, but its pressure is always identical to that of its environment. You will be considering parcel temperature changes in more detail later. For now, let's just examine parcels that are displaced vertically along dry adiabats.

For example, in Fig. 1, if a parcel is forced upward dry adiabatically, it becomes colder than its surroundings. Therefore, its density becomes greater than its environment and the parcel's upward displacement is decelerated. Conversely, a parcel forced downward becomes warmer than its environment, so its displacement is also opposed by buoyancy. This situation is stable.

However, if we consider an unstable environment like the example in Fig. 2, the lifted parcel finds itself warmer than the environment. Like a rising hot air balloon, it is now less dense than its surroundings, and its upward displacement is accelerated. The neutral situation is shown in Fig. 3, where the environment and the parcel change temperature at the same rate: the dry adiabatic rate.

Therefore, the lapse rate in the environment (as seen in a sounding) determines the dry static stability of that environment. We refer to the stability in this manner because condensation is not involved, and we are considering the sounding as fixed or static. You will be examining stability in other ways.

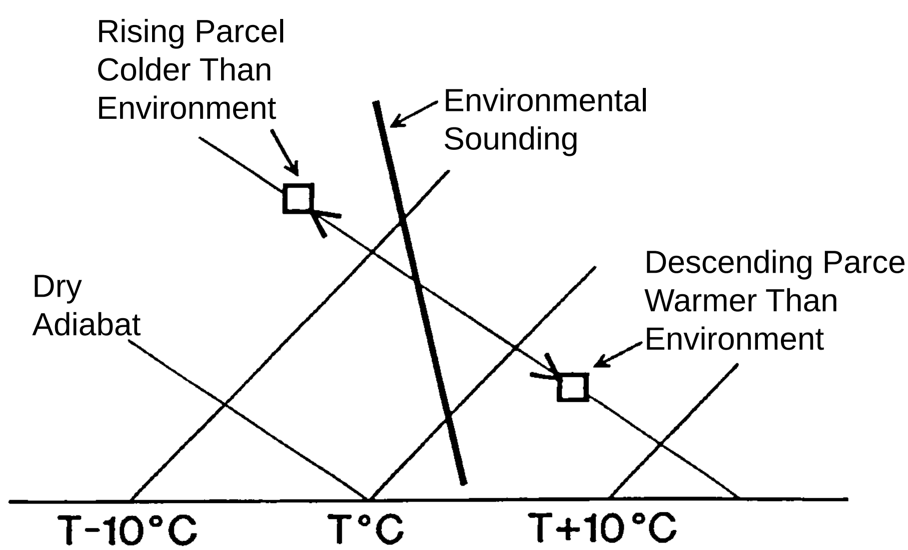

Figure 1. Diagram showing the temperature of a parcel moving up and down along a dry adiabat in a stable environment.

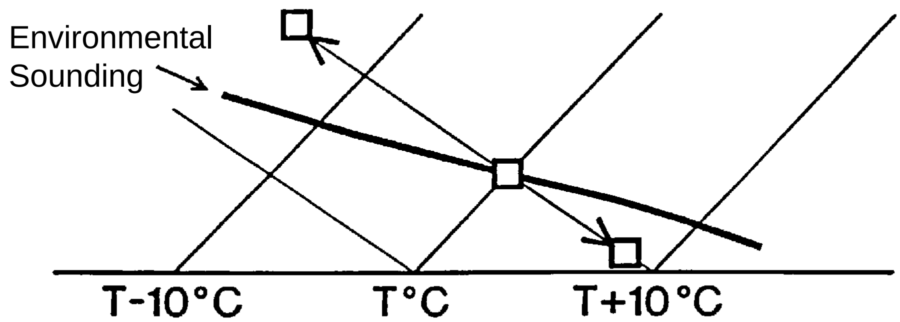

Figure 2. As in Fig. 1, except in an unstable (superadiabatic) environment.

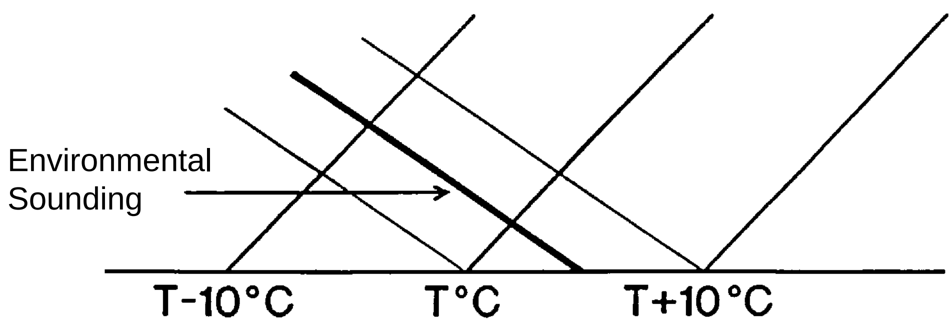

Figure 3. As in Fig. 1, except in a neutral (dry adiabat) environment.