THE
ATMOSPHERIC RESERVOIR
Examining the Atmosphere and Atmospheric Resource Management

Atmospheric Stability

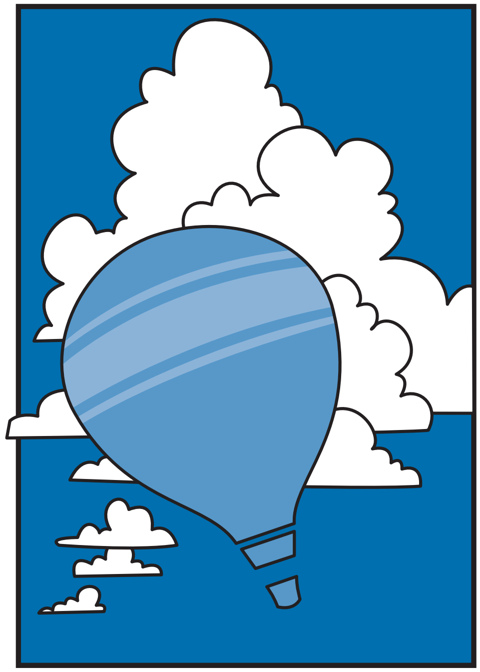
by Bruce Boe

"The atmosphere will destabilize tonight and tomorrow, causing scattered showers and perhaps a few thunderstorms." Similar words are often heard during weathercasts this time of year, and throughout our warm seasons. Why?

The primary answer can be found in one word: temperature. A basic truth is that in a free environment, warmer air rises. The classic example of this is the hot air balloon. As air rises, it expands (as the pressure drops), and cools. When a warm, buoyant volume of air rises, the temperature of the atmosphere though which it ascends also changes.

On the average, our atmosphere cools by 3.5ºF for each additional 1,000 ft. in height. Rising air, free of cloud, cools slightly faster, at about 5.5ºF per 1,000 ft. Because of this tendency, rising air usually cools enough that, after a rise of a few thousand feet, its temperature falls to that of the surrounding atmosphere. When this happens, the air "parcel" ceases rising.

If a parcel rises far enough, it will eventually cool sufficiently that condensation occurs, and clouds result. With condensation, a curious thing occurs: the rate of cooling *slows down*. When water evaporates, a great deal of energy is stored within the resulting invisible water vapor. This energy, termed *latent heat*, is the energy required to change the water from a liquid to a gas. The heat doesn't just vanish though, it is stored within the higher-energy water vapor molecules. When condensation



occurs, this latent heat is released, actually warming the condensing volume! Thus, the rate of cooling slows. The more condensation, the more latent heat is released, and the slower the cooling becomes.

When the rate of cooling slows enough, the parcel of rising air may stay warmer than the surrounding atmosphere for many tens of thousands of feet. The tall, billowing white cloud tower that results we quickly recognize as a rain shower—or in the ultimate case, a thunderstorm.

Instability is found when the region near the surface from which the air parcels originate is warm, and when the air aloft is cold. This maximizes the height to which parcels may rise before cooling to equilibrium with the environment.

If the rising air is also moist, this improves the odds of cloud development too, for condensation occurs faster in moist air, and the sooner condensation occurs, the sooner the rate of cooling slows. And so it goes.

A final observation. . .the air's ability to hold moisture depends mostly on its temperature. Warm air can hold many times more water vapor than can colder air. Because of this, cold-season air masses are on average significantly drier than their warm-season cousins. Condensation is slower, and less total water vapor is condensed. This means less latent heat is released, and rising parcels cool to equilibrium temperatures much sooner.

This is the main reason why we have few thunderstorms during the winter—the low level air is usually too cold to contain much moisture, or to rise very far within the surrounding atmosphere. Not that this can't happen. . .on February 25, 1998, much of southern and eastern North Dakota experienced thundershowers or *thundersnow* during the afternoon and evening hours!

However, it is normally this time of year when we first notice the crisp, white, cumuliform cloud towers borne in afternoons of the warm air near the surface, coupled with cool air aloft. This is atmospheric instability on display! ■

Atmospheric Resource Board
North Dakota State Water Commission
900 East Boulevard, Bismarck, ND 58505
701) 328-2788
Internet: http://www.swc.state.nd.us/ARB/

ND Weather Modification Association
PO Box 2599, Bismarck, ND 58502
701) 223-4232