Inversions

An inversion occurs when air temperature increases with altitude. This situation occurs frequently but is generally confined to a relatively shallow layer. Plumes emitted into air layers that are experiencing an inversion (inverted layer) do not disperse very much as they are transported with the wind. Plumes that are emitted above or below an inverted layer do not penetrate that layer, rather these plumes are trapped either above or below that inverted layer. An example of the lapse rate for an inversion is depicted in Figure 4-13. High concentrations of air pollutants are often associated with inversions since they inhibit plume dispersion. The four major types of inversions are caused by different atmospheric interactions and can persist for different amounts of time.

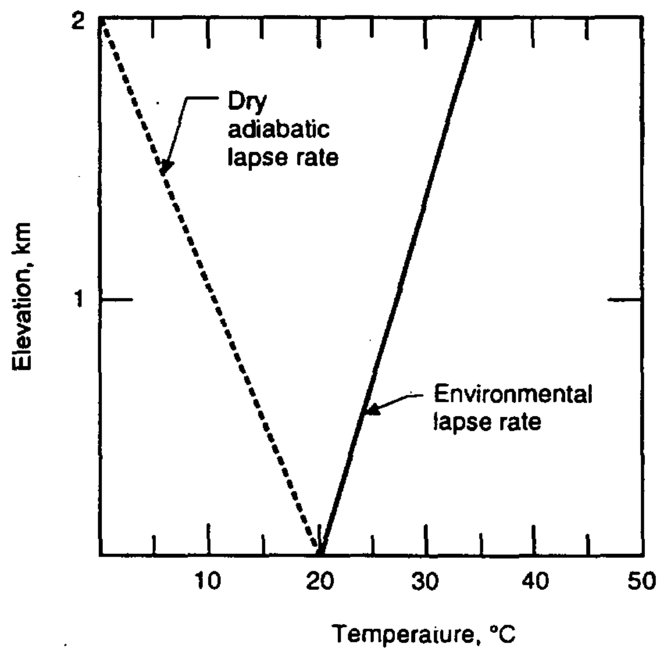

Figure 4-13. Temperature inversion

Radiation

The **radiation inversion** is the most common form of surface inversion and occurs when the earth's surface cools rapidly. As the earth cools, so does the layer of air close to the surface. If this air cools to a temperature below that of the air above, it becomes very stable, and the layer of warmer air impedes any vertical motion.

Radiation inversions usually occur in the late evening through the early morning under clear skies with calm winds, when the cooling effect is greatest. The same conditions that are conducive to nocturnal radiation inversions are also conducive to instability during the day. Diurnal cycles of daytime instability and nighttime inversions are relatively common. Therefore, the effects of radiation inversions are often short-lived. Pollutants trapped by the inversions are dispersed by vigorous vertical mixing after the inversion breaks down shortly after sunrise. Figure 4-14 illustrates this diurnal cycle.

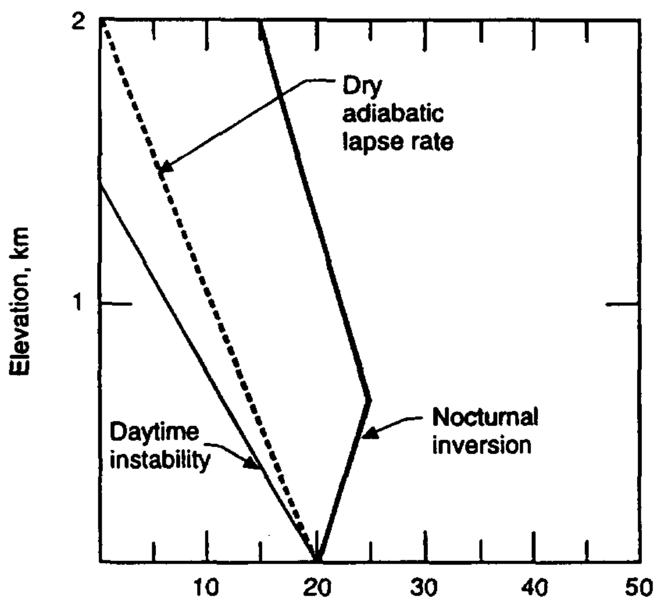

Figure 4-14. Diurnal cycle

In some cases, however, the daily warming that follows a nocturnal radiation inversion may not be strong enough to erode the inversion layer. For example, thick fog may accompany the inversion and reduce the effect of sunlight the next day. Under the right conditions, several days of radiation inversion, with increasing pollutant concentrations, may result. This situation is most likely to occur in an enclosed valley, where nocturnal, cool, downslope air movement can reinforce a radiation inversion and encourage fog formation.

In locations where radiation inversions are common and tend to be relatively close to the surface, tall stacks that emit pollutants above the inversion layer can help reduce surface-level pollutant concentrations.

Subsidence

The **subsidence inversion** (Figure 4-15) is almost always associated with anticyclones (high pressure systems). Recall that air in an anticyclone descends and flows outward in a clockwise rotation. As the air descends, the higher pressure at lower altitudes compresses and warms it at the dry adiabatic lapse rate. Often this warming occurs at a rate faster than the environmental lapse rate. The inversion layer thus formed is often elevated several hundred meters above the surface during the day. At night, because of the surface air cooling, the base of a subsidence inversion often descends, perhaps to the ground. In fact, the clear, cloudless days characteristic of anticyclones encourage radiation inversions, so that there may be a surface inversion at night and an elevated inversion during the day. Although the mixing layer below the inversion may vary diurnally, it will never become very deep.

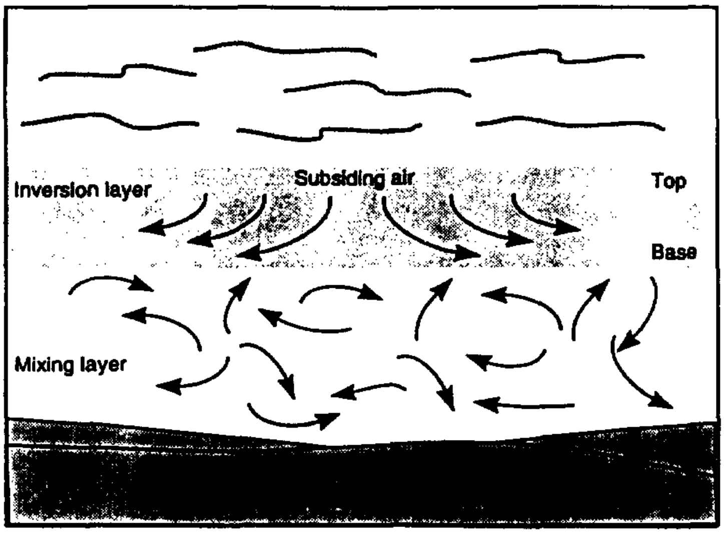

Figure 4-15. Subsidence inversion

Subsidence inversions, unlike radiation inversions, last a relatively long time. This is because they are associated with both the semipermanent anticyclones centered on each ocean and the slow-moving migratory anticyclones moving generally west to east in the United States.

When an anticyclone stagnates, pollutants emitted into a mixing layer cannot be diluted. As a result, over a period of days, pollutant concentrations may rise. The most severe air pollution episodes in the United States have occurred either under a stagnant migratory anticyclone (for example, New York in November, 1966 and Pennsylvania in October, 1948) or under the eastern edge of the Pacific semipermanent anticyclone (Los Angeles).

Frontal

Lesson 3 mentions frontal trapping, the inversion that is usually associated with both cold and warm fronts. At the leading edge of either front, the warm air overrides the cold, so that little vertical motion occurs in the cold air layer closest to the surface (Figure 4-16). The strength of the inversion depends on the temperature difference between the two air masses. Because fronts are moving horizontally, the effects of the inversion are usually short-lived, and the lack of vertical motion is often compensated by the winds associated with the frontal passage.

However, when fronts become stationary, inversion conditions may be prolonged.

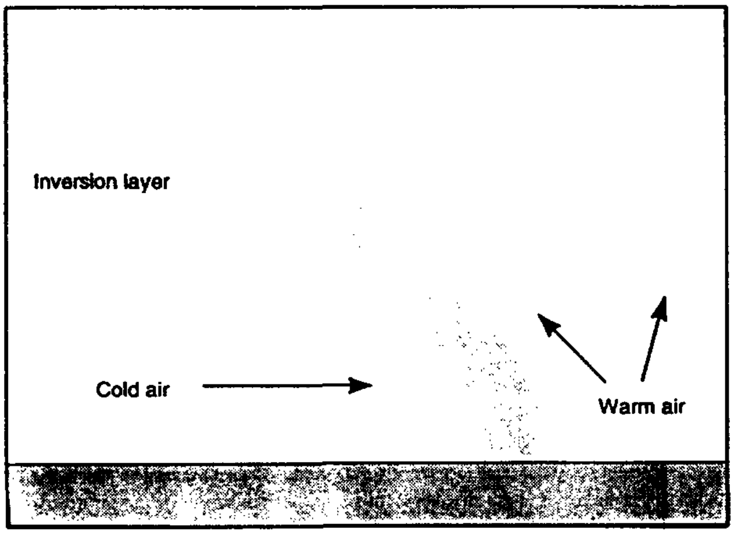

Figure 4-16. Frontal inversion (cold front)

Advection

Advection inversions are associated with the horizontal flow of warm air. When warm air moves over a cold surface, conduction and convection cools the air closest to the surface, causing a surface-based inversion (Figure 4-17). This inversion is most likely to occur in winter when warm air passes over snow cover or extremely cold land.

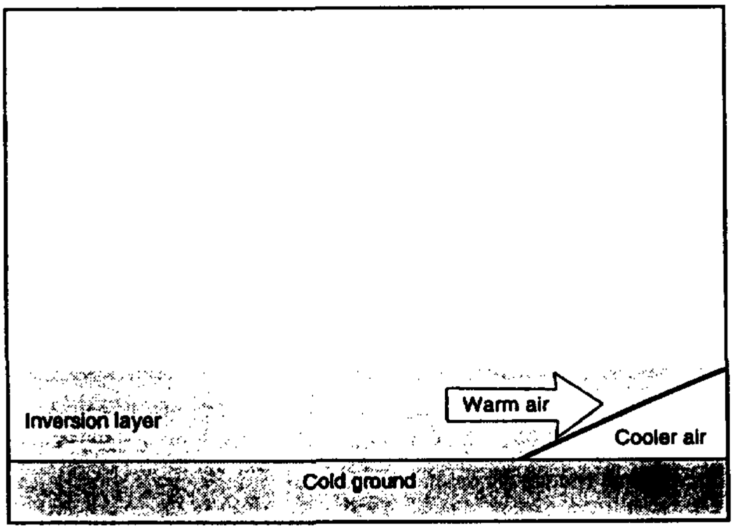

Figure 4-17. Surface-based advection inversion

Another type of advection inversion develops when warm air is forced over the top of a cooler air layer. This kind of inversion is common on the eastern slopes of mountain ranges (Figure 4-18), where warm air from the west overrides cooler air on the eastern side of the mountains. Denver often experiences such inversions. Both kinds of advection inversions are vertically stable but may have strong winds under the inversion layer.

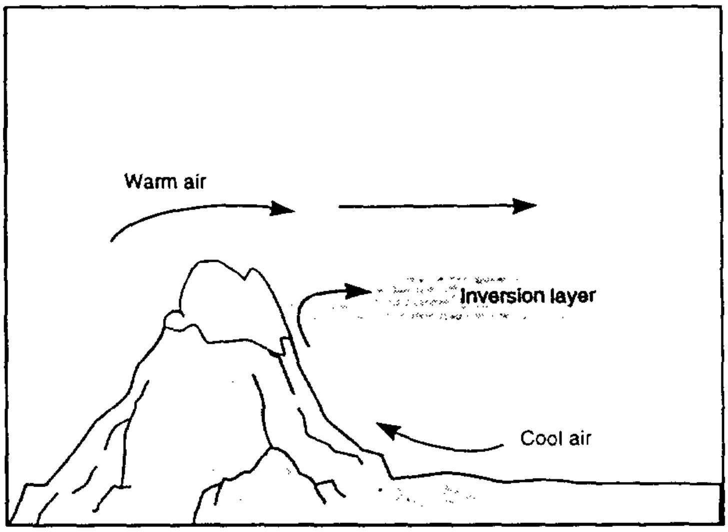

Figure 4-18. Terrain-based advection inversion

Stability and Plume Behavior

The degree of atmospheric stability and the resulting mixing height have a large effect on pollutant concentrations in the ambient air. Although the discussion of vertical mixing did not include a discussion of horizontal air movement, or wind, you should be aware that horizontal motion does occur under inversion conditions. Pollutants that cannot be dispersed upward may be dispersed horizontally by surface winds.

The combination of vertical air movement and horizontal air flow influences the behavior of plumes from point sources (stacks). Lesson 6 will discuss plume dispersion in greater detail. However, this lesson will describe several kinds of plumes that are characteristic of different stability conditions.

The **looping plume** of Figure 4-19 occurs in highly unstable conditions and results from turbulence caused by the rapid overturning of air. While unstable conditions are generally favorable for pollutant dispersion, momentarily high ground-level concentrations can occur if the plume loops downward to the surface.