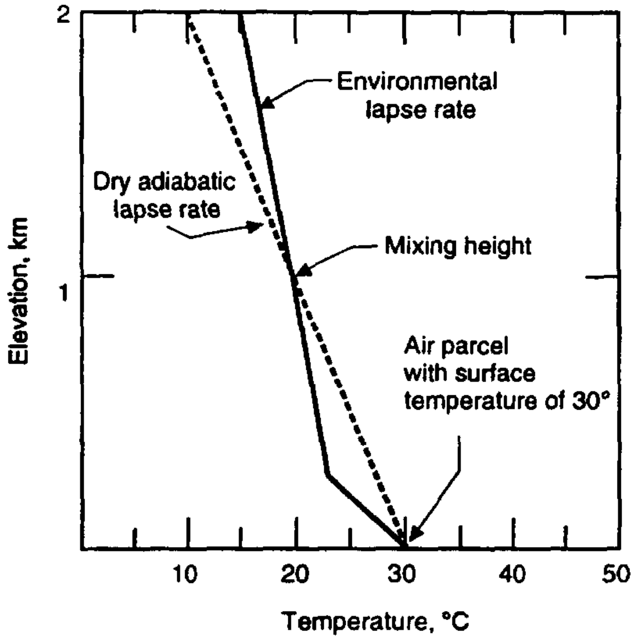


Figure 4-6. Mixing height

Atmospheric Stability

The degree of stability of the atmosphere is determined by the temperature difference between an air parcel and the air surrounding it. This difference can cause the parcel to move vertically (i.e., it may rise or fall). This movement is characterized by four basic conditions that describe the general stability of the atmosphere. In **stable** conditions, this vertical movement is discouraged, whereas in **unstable** conditions the air parcel tends to move upward or downward and to continue that movement. When conditions neither encourage nor discourage air movement beyond the rate of adiabatic heating or cooling, they are considered **neutral**. When conditions are extremely stable, cooler air near the surface is trapped by a layer of warmer air above it. This condition, called an **inversion**, allows virtually no vertical air motion. These conditions are directly related to pollutant concentrations in the ambient air.

Unstable Conditions

Remember that an air parcel that begins to rise will cool at the dry adiabatic lapse rate until it reaches the dew point at which point it will cool at the wet adiabatic lapse rate. This assumes that the surrounding atmosphere has a lapse rate greater than the adiabatic lapse rate (cooling at more than 9.8°C/1000 m), so that the rising parcel will continue to be warmer than the surrounding air. This is a **superadiabatic lapse** rate. As Figure 4-7 shows, the temperature difference between the actual environmental lapse rate and the dry adiabatic lapse rate actually increases with height, and buoyancy is enhanced.

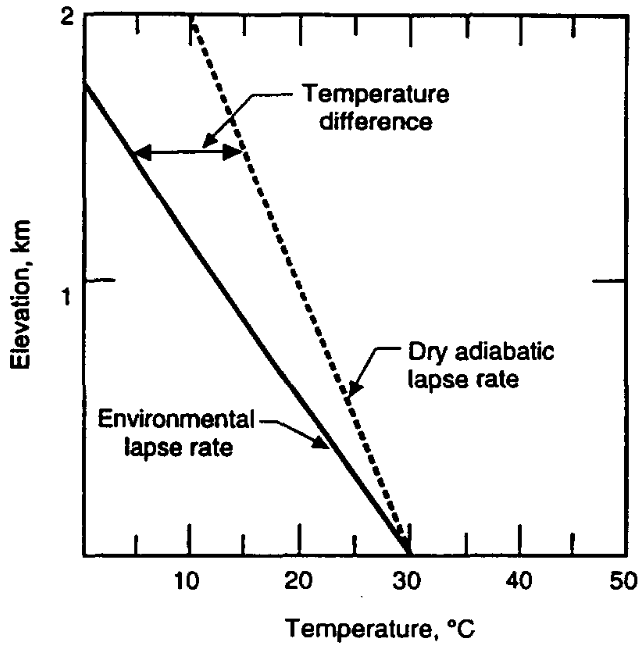


Figure 4-7. Enhanced buoyancy associated with instability (superadiabatic lapse rate)

As the air rises, cooler air moves underneath. It, in turn, may be heated by the earth's surface and begin to rise. Under such conditions, vertical motion in both directions is enhanced, and considerable vertical mixing occurs. The degree of instability depends on the degree of difference between the environmental and dry adiabatic lapse rates. Figure 4-8 shows both slightly unstable and very unstable conditions.

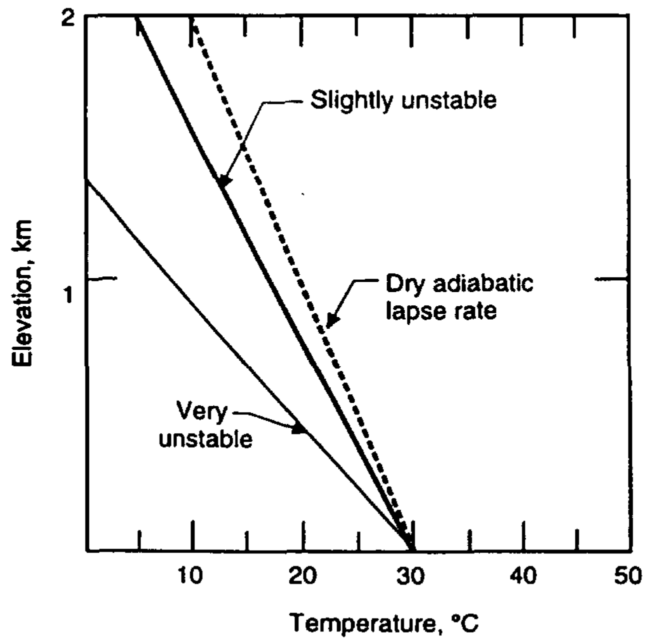


Figure 4-8. Unstable conditions

Unstable conditions most commonly develop on sunny days with low wind speeds where strong insolation is present. The earth rapidly absorbs heat and transfers some of it to the surface air layer. There may be one buoyant air mass if the thermal properties of the surface are uniform, or there may be numerous parcels if the thermal properties vary. The air warms, becomes less dense than the surrounding air and rises.

Another condition that may lead to instability is the cyclone (low pressure system), which is characterized by rising air, clouds, and precipitation.

Neutral Conditions

When the environmental lapse rate is the same as the dry adiabatic lapse rate, the atmosphere is in a state of neutral stability (Figure 4-9). Vertical air movement is neither encouraged nor hindered. The neutral condition is important as the dividing line between stable and unstable conditions. Neutral stability occurs on windy days or when there is cloud cover such that strong heating or cooling of the earth's surface is not occurring.

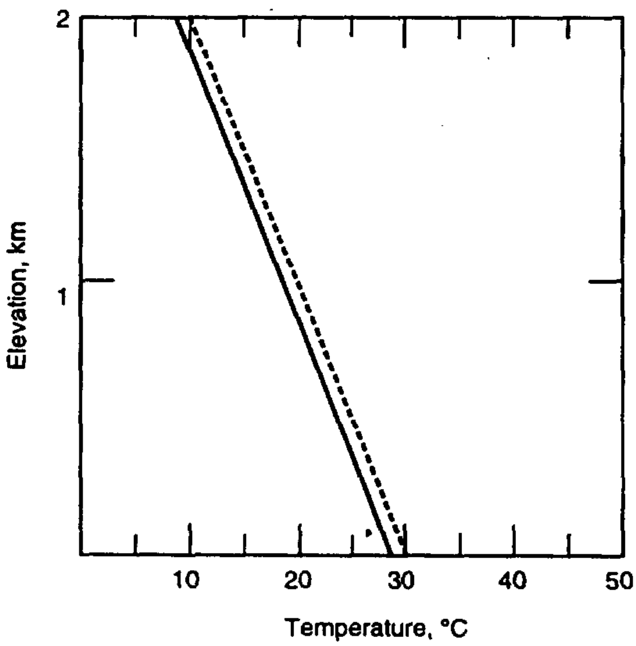


Figure 4-9. Neutral conditions

Stable Conditions

When the environmental lapse rate is less than the adiabatic lapse rate (cools at less than 9.8°C/1000 m), the air is stable and resists vertical motion. This is a **subadiabatic lapse** rate. Air that is lifted vertically will remain cooler, and therefore more dense than the surrounding air. Once the lifting force is removed, the air that has been lifted will return to its original position (Figure 4-10). Stable conditions occur at night when there is little or no wind.

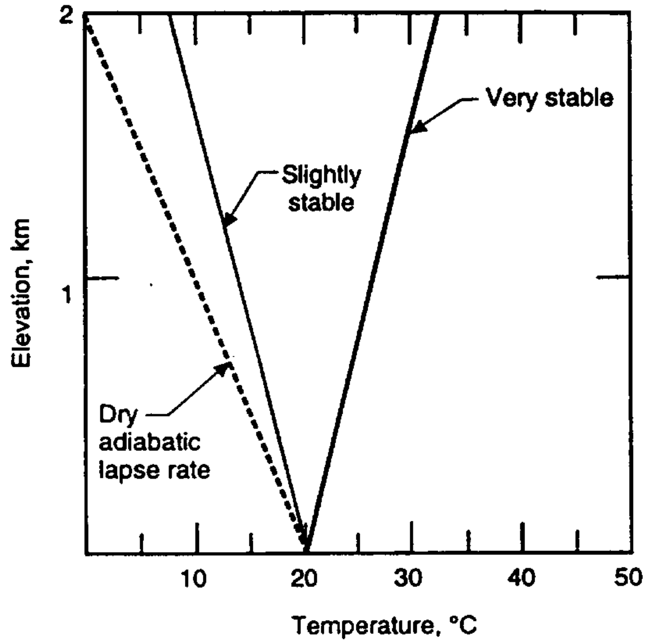


Figure 4-10. Stable conditions

Conditional Stability and Instability

In the previous discussion of stability and instability, we have assumed that a rising air parcel cools at the dry adiabatic lapse rate. Very often, however, the air parcel becomes saturated (reaches its dew point) and begins to cool more slowly, at the wet adiabatic lapse rate. This change in the rate of cooling may change the conditions of stability. Conditional instability occurs when the environmental lapse rate is greater than the wet adiabatic lapse rate but less than the dry rate. This is illustrated in Figure 4-11. Stable conditions occur up to the condensation level and unstable conditions occur above it.

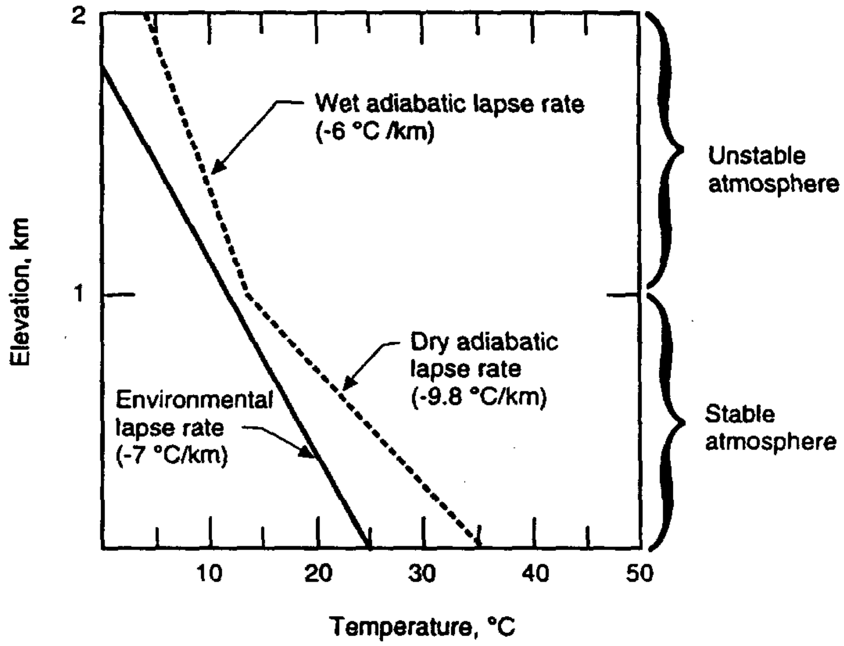


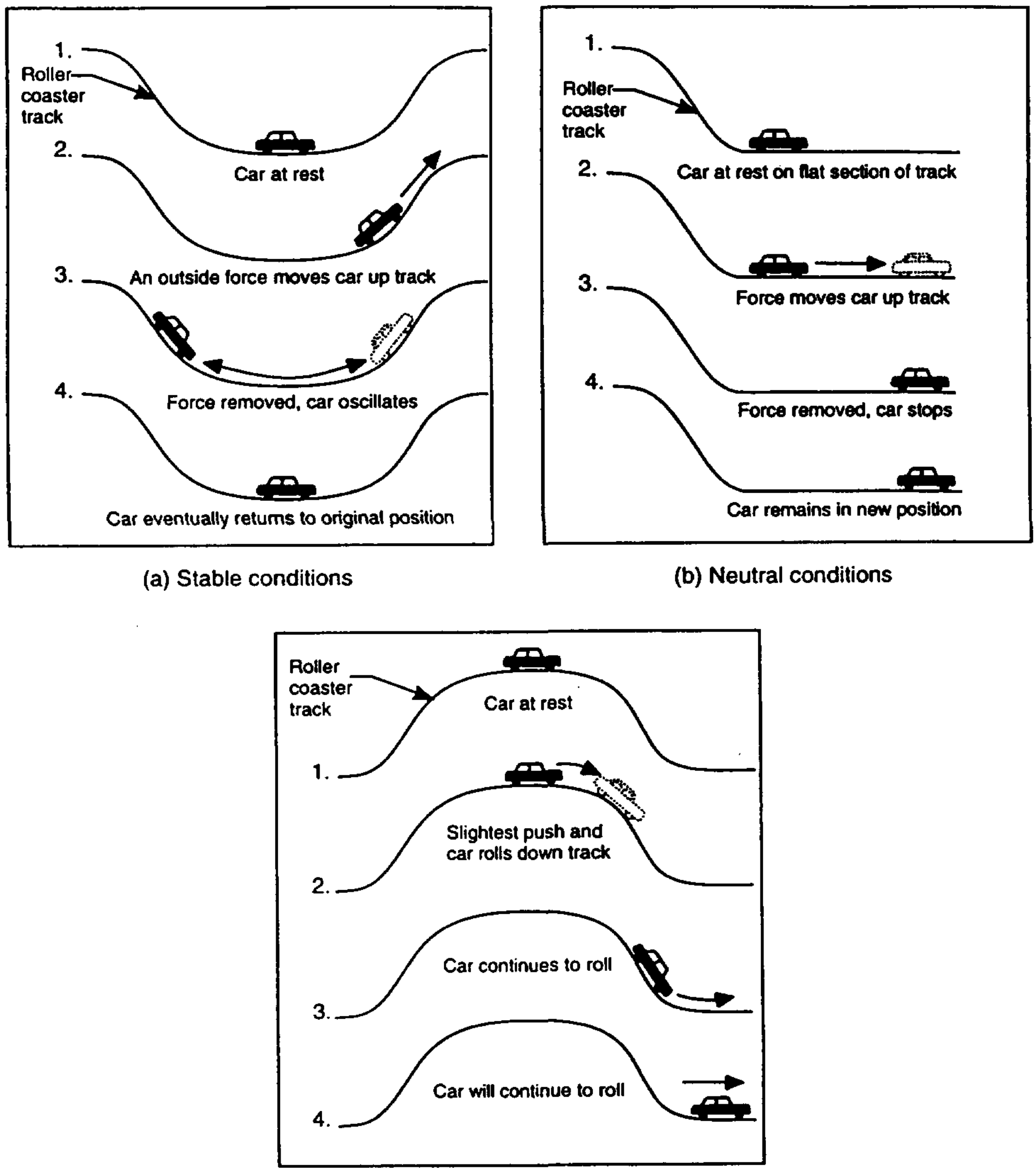
Figure 4-11. Conditional stability

Illustration of Atmospheric Stability Conditions

Figure 4-12 illustrates the various stability categories. These analogies are intended to illustrate the different atmospheric stability conditions. Figure 4-12 (a) depicts stable atmospheric conditions. Notice that when the lifting force is removed, the car eventually returns to its original position. Since the car resists displacement from its original position, it is in a stable environment.

Figure 4-12 (b) depicts neutral conditions. When a force is applied to the car it moves as long as the force is maintained. When the force is removed, the car stops and remains in its new position. This condition represents neutral stability.

Figure 4-12 (c) depicts unstable conditions. Once a force is applied to the car it will continue to move even after the force is removed.



(a) Stable conditions

(b) Neutral conditions

(c) Unstable conditions

Figure 4-12. Atmospheric stability conditions

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.

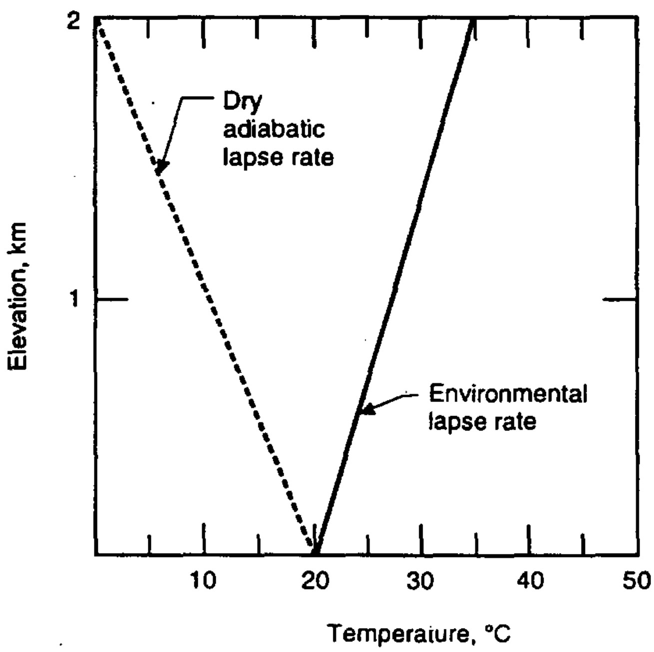


Figure 4-13. Temperature inversion

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.