A warm layer limits mixing

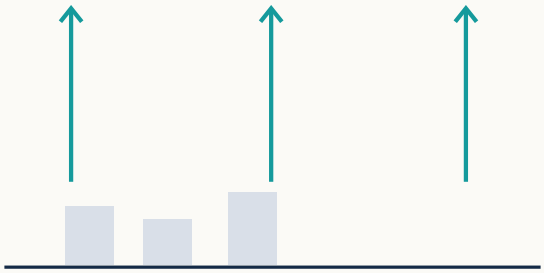
In the lower atmosphere, temperature usually decreases with height. A thermal inversion reverses that trend within a layer: temperature increases upward, with warmer air above cooler air.

1. CONTRAST THE TWO AIR PROFILES

DAYTIME MIXING

Cooler air above

Rising and mixing air

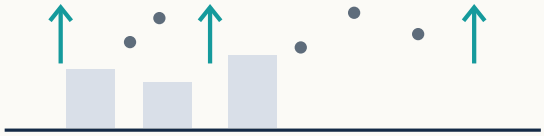


Sun-warmed ground + sources

INVERSION

WARMER AIR: STABLE CAP

Cooler air + pollutants below



Emission sources

Schematic: arrows show vertical movement, not wind speed.

2. WHY COOL AIR DOES NOT RISE THROUGH THE CAP

An air parcel rises freely while it remains less dense than the surrounding air. In an inversion, a rising parcel becomes cooler and denser than the warmer air around it, resisting further ascent. The stable layer therefore suppresses vertical exchange; it is not a solid barrier.

3. WHAT THIS MEANS FOR AIR QUALITY

Emitted pollutants have less opportunity to disperse upward. Smog and particulate matter can accumulate near the surface, where people breathe. An inversion changes dispersion, not the original emission source. Its presence alone does not prove emissions have increased.

Temperature profile, stability and haze: Hong Kong Observatory, Inversion Layer.
Stable caps and parcel buoyancy: National Weather Service, The Inversion.

Scope: College Board AP Environmental Science CED, Topic 7.3, p. 143.

How an inversion develops

Formation depends on weather and geography. Surface cooling is one common pathway; an inversion can also form above the surface. A valley is not required for an inversion.

1. A CLEAR, CALM NIGHT: RADIATION INVERSION

A

Ground loses energy

At night the surface emits infrared radiation. With little cloud cover, net cooling can be strong.

B

Air near the ground cools

The ground cools the air next to it. Air higher up stays relatively warmer, reversing the temperature trend.

C

Weak mixing preserves the layers

Light winds provide little turbulent exchange, allowing cooler air to remain beneath warmer air.

2. VALLEYS CAN HOLD A POOL OF COLD AIR

Cool, dense air can settle into low-lying terrain. Surrounding slopes and a stable air layer may limit ventilation, allowing local emissions to accumulate. Inversions also occur over flatter land and coastal areas; mountains intensify some episodes but do not define an inversion.

3. EXTENSION: FORMATION ALOFT AND BREAKUP

Subsidence: sinking air under high pressure compresses and warms. A warm layer aloft may cap cooler air underneath. This can limit the depth of near-surface mixing even when the ground is not especially cold.

Breakup: daytime surface warming often weakens a shallow nighttime inversion. Increased mixing or a change in the weather may also disperse trapped air. Strong or persistent inversions may survive daytime heating; sunrise is not a guaranteed reset.

Radiative cooling and erosion of inversions: National Weather Service, The Inversion.
Subsidence, mixing depth and persistence: National Weather Service, Marine Layer.
Valley terrain and pollutant buildup: Utah Department of Environmental Quality, Inversions.

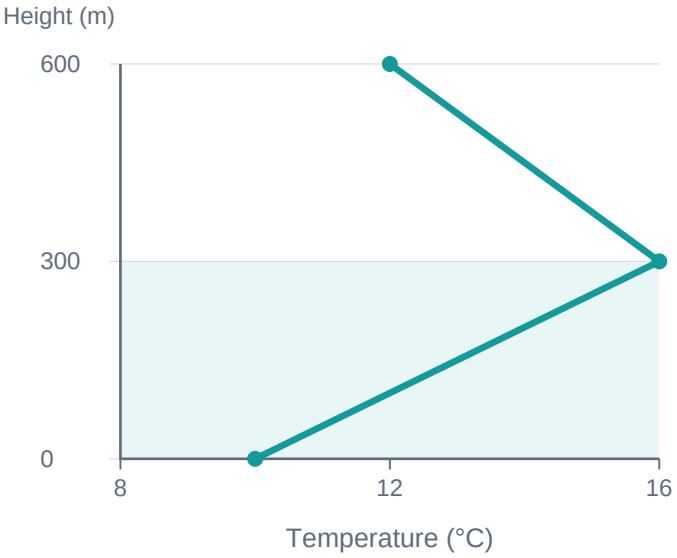
Scope: College Board AP Environmental Science CED, Topic 7.3, p. 143.

Read the profile, explain the risk

A temperature–height profile reveals the vertical air structure. Pair that profile with pollution measurements to explain an air-quality episode; haze by itself does not identify an inversion.

1. LOCATE WHERE TEMPERATURE INCREASES UPWARD

Illustrative surface-based inversion; not field observations.



0–300 m: INVERSION

Temperature rises from 10°C to 16°C. The shaded layer is stable and inhibits upward mixing.

300–600 m: COOLING

Temperature falls to 12°C above the inversion. The whole atmosphere does not have to warm upward.

2. EMISSION RATE IS NOT CONCENTRATION

Similar emissions can produce different air quality when wind and mixing change. Compare temperature profiles, wind, pollutant concentrations and source activity before concluding that a higher concentration means more emissions.

3. EXTENSION: A SIMPLE MIXING-VOLUME MODEL

For pollutant mass evenly mixed through a fixed area, concentration = mass ÷ volume. Halving the mixing depth halves the volume, so the model predicts twice the concentration.

Real episodes also involve transport, chemistry, deposition and changing emissions. This simplified model illustrates dilution; it does not forecast an actual concentration or establish whether a health threshold was exceeded.

Interpreting an inversion profile: Hong Kong Observatory, Inversion Layer.
Limits on mixing depth: National Weather Service, Marine Layer Information.

Scope: College Board AP Environmental Science CED, Topic 7.3, p. 143.