TRANSPORT AND DISPERSION OF AIR POLLUTANTS

Air Pollution II

4th Year Class

Lecture 1

Dr. Husam T. Majeed

Atmospheric Stability and Plume Behavior

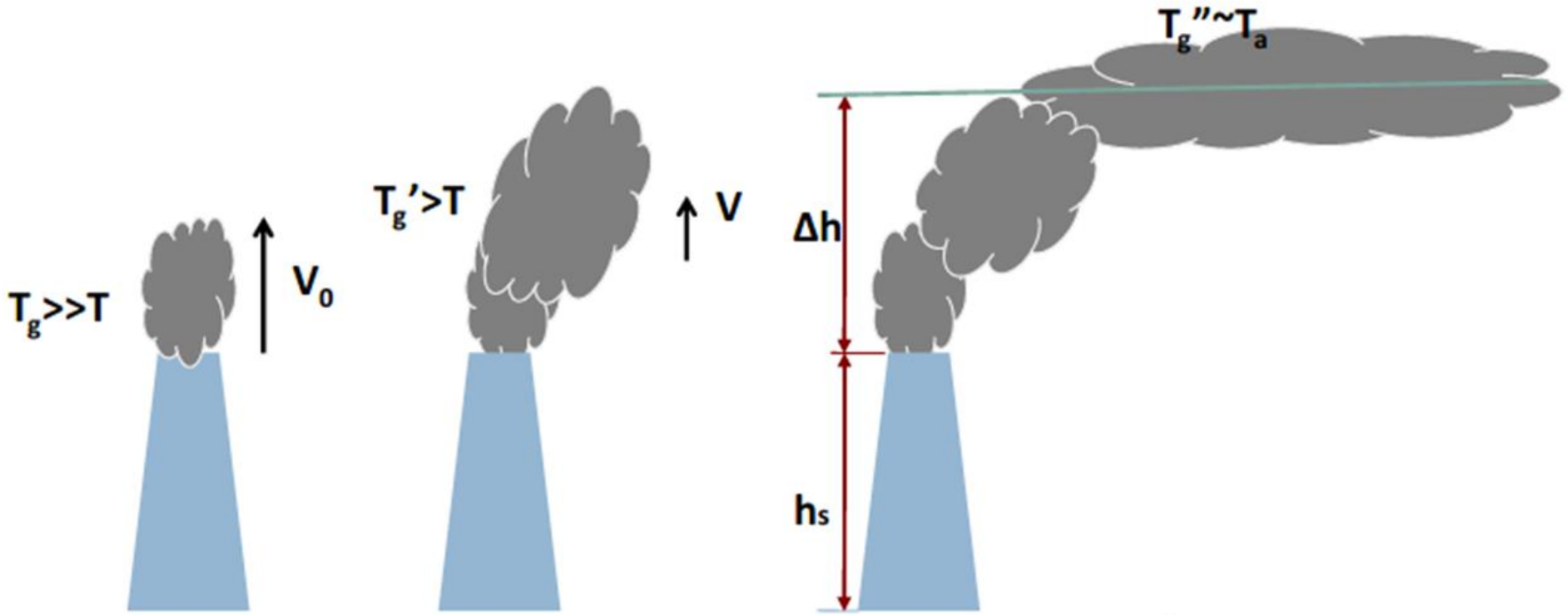
INTRODUCTION

- Pollutants enter the atmosphere in a number of different ways. For example

- wind blows dust into the air.
- Automobiles, trucks and buses emit pollutants from engine exhausts and during refueling.
- Electric power plants
- home furnaces

- One method of pollution release from stationary point sources has received more attention than any other: **stacks**
- As the exhaust gases and pollutants leave a stack, they mix with ambient air describing a **plume.**
- As the plume travels downwind, the plume diameter grows and it progressively spreads and disperses.

- Gases leaving the tops of stacks rise higher than the stack top when they are either of lower density than the surrounding air (**buoyancy rise)** or ejected at a velocity high enough to give the exit gases upward kinetic energy (**momentum rise).**



- After this initial stage, the **dispersion of pollutants** in the atmosphere is the result of the following three mechanisms:

1) General air motion that transports pollutants downwind
2) Turbulent velocity fluctuations that disperse pollutants in all directions
3) Diffusion due to concentration gradients.

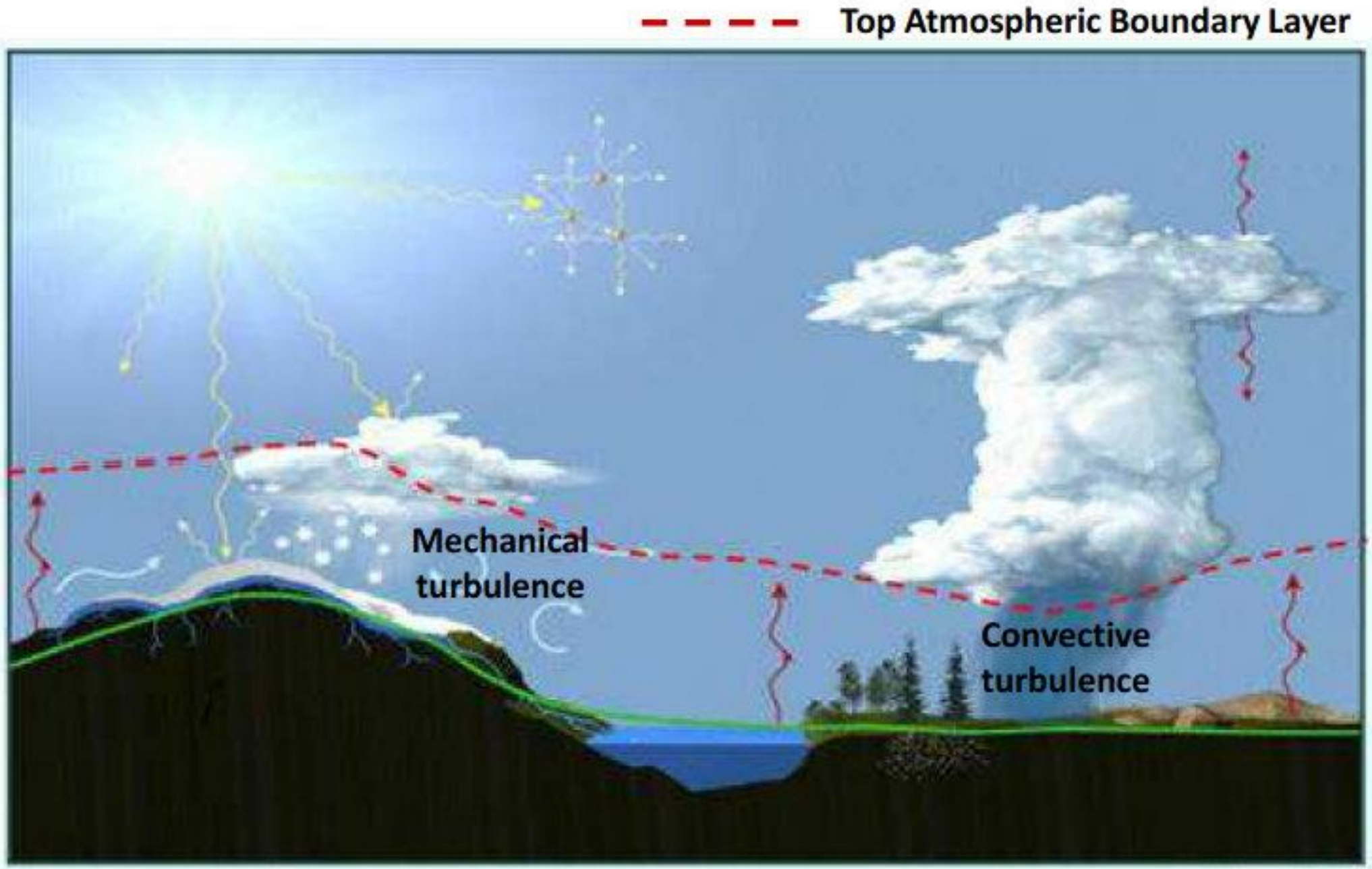
Turbulence

- Turbulence is highly irregular motion of the wind.
- There are basically two different causes of turbulent eddies:

  mechanical turbulence and

  convective turbulence.
- While both of them are usually present in any given atmospheric condition, either mechanical or convective turbulence prevails over the other.

- Mechanical turbulence is caused by physical obstructions to normal flow such as mountains, building, trees,...
- Degree of mechanical turbulence depends on wind speed and roughness of the obstructions.
- Convective turbulence results from different heating-cooling of surfaces and air masses. The higher the temperature difference, the greater the turbulence is.



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Atmospheric Boundary Layer (ABL)

- Most turbulent and pollutant dispersion processes occur in the ABL.
- ABL is the bottom layer of the troposphere.
- ABL thickness is ≈ 1000 m, but quite variable (100 m- 4000 m) in time and space.
- The configuration of the flow is quite variable too:
  laminar during night-time hours and **turbulent** during daytime.
- It can be divide into two layers, namely:
  - **Surface Boundary Layer** (SBL) and
  - **Planetary Boundary Layer** (PBL)
- The ABL is the most important layer with respect to air pollution.
- Almost all of the airborne pollutants emitted into the ambient atmosphere are transported and dispersed within the ABL.

ATMOSPHERIC STABILITY

- One of the most important characteristics in intensity of turbulence in the atmosphere is its **stability**.
- Stability is the tendency to resist vertical motions or to suppress existing turbulence).
- The atmospheric stability is related to the variation with altitude of

temperature, pressure humidity

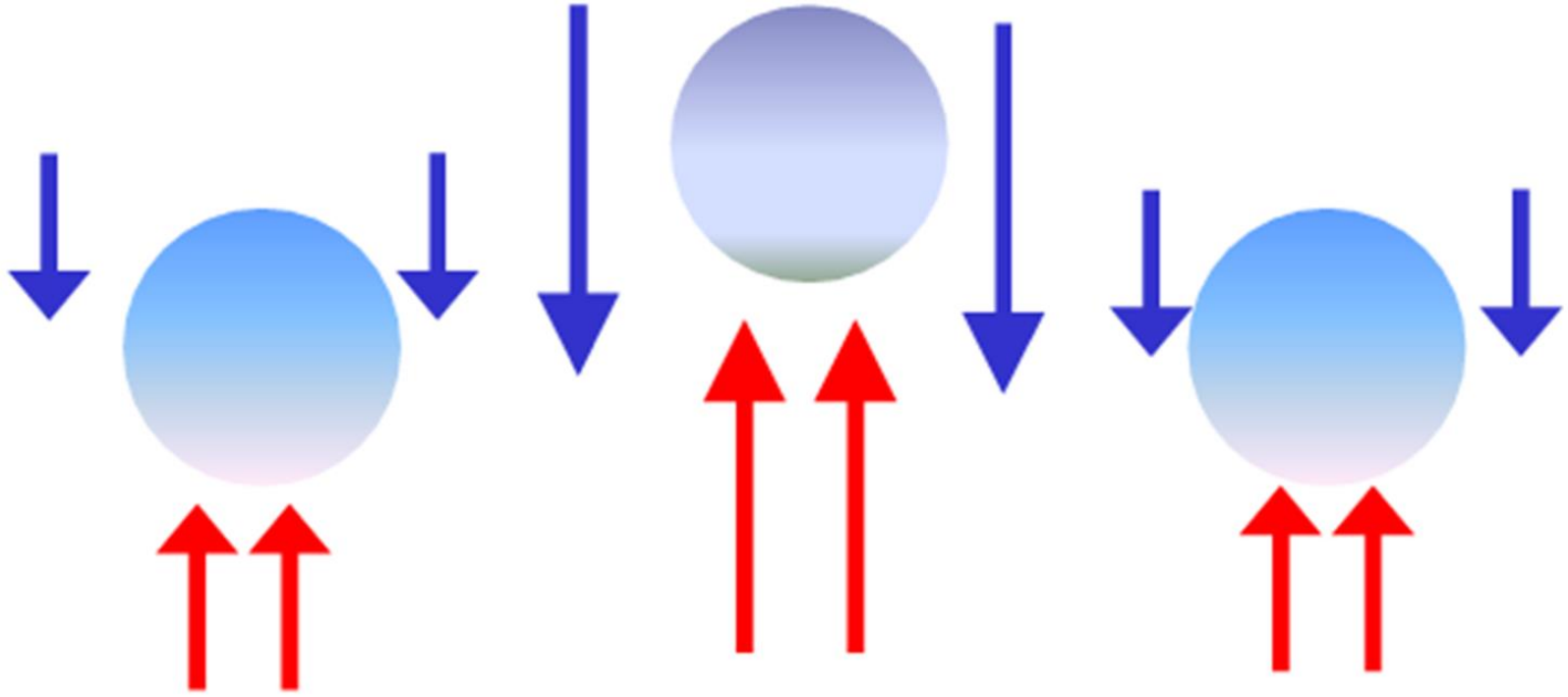
- Holding other conditions constant, the temperature of air increases as atmospheric pressure increases and conversely decreases as pressure decreases.
- With respect to the atmosphere, where air pressure decreases with rising altitude, the normal temperature profile of the troposphere is one where temperature decreases with height.

- An air parcel that becomes warmer than the surrounding air begins to expand and cool
- As long as the parcel's temperature is greater that the surrounding air, the parcel is less dense than the cooler surrounding air. Therefore, it rises, or is buoyant.
- As the parcel rises, it expands thereby decreasing its pressure and, therefore, its temperature decreases as well.
- The initial cooling of an air parcel has the opposite effect.

Assuming that:

1. The air parcel is a relatively well-defined body of air that it does not mix with the surrounding air.
2. The exchange of heat between the air parcel and its surrounding is minimal: it does not gain or lose heat (adiabatic process) and,
3. This raising (falling) air parcel cools (heats) without reaching its dew point, that is, without saturation, any water in it remains in a gaseous state (dry air).

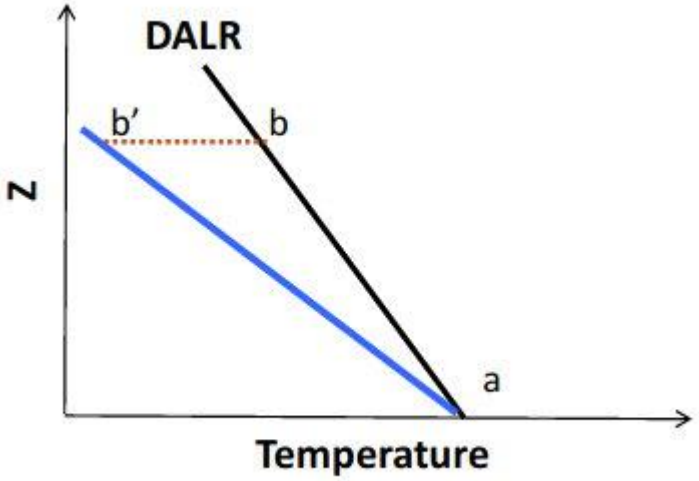
- Likewise, the rate of cooling (or warming) of the air parcel forced
- to rise or descend is about -9.76 (+9.76) °C·km^{-1}. This is the **dry**
- **adiabatic** profile or **dry adiabatic lapse rate (DALR)**.



Warm air rises and cools, while cool air descends and warms

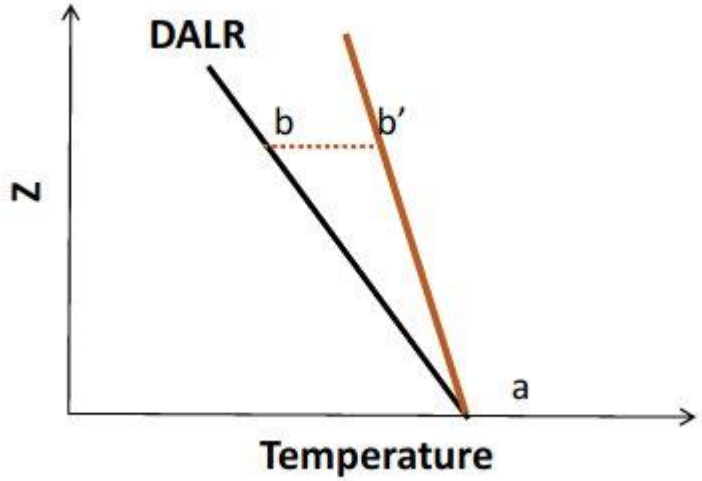
- The extent to which an air parcel rises or falls depends on the relationship of its temperature to that of the surrounding air.
- Thus, the **degree of stability** of the atmosphere can be determined from comparing the **DALR** and the **environmental lapse rates**.
- Warm air rises and cools, while cool air descends and warms

Unstable



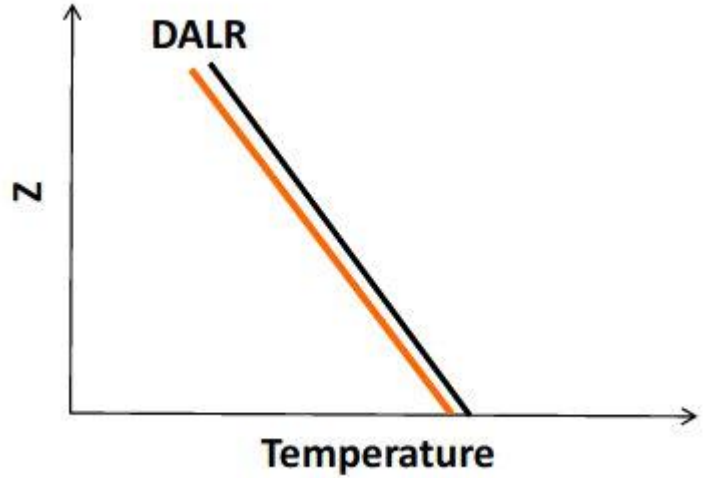
The parcel will continue to rise.

Stable



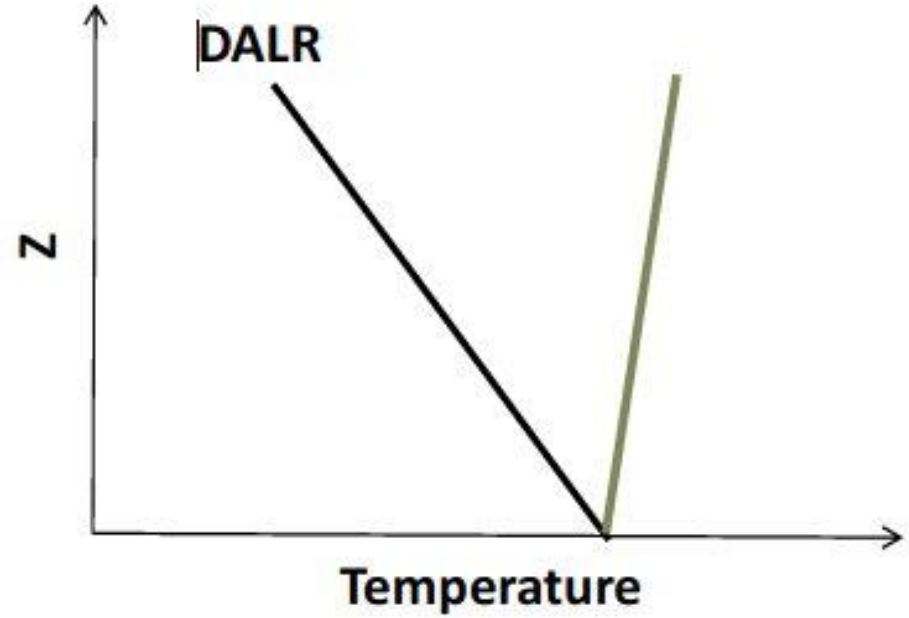
The parcel will sink back to its original level

Neutral



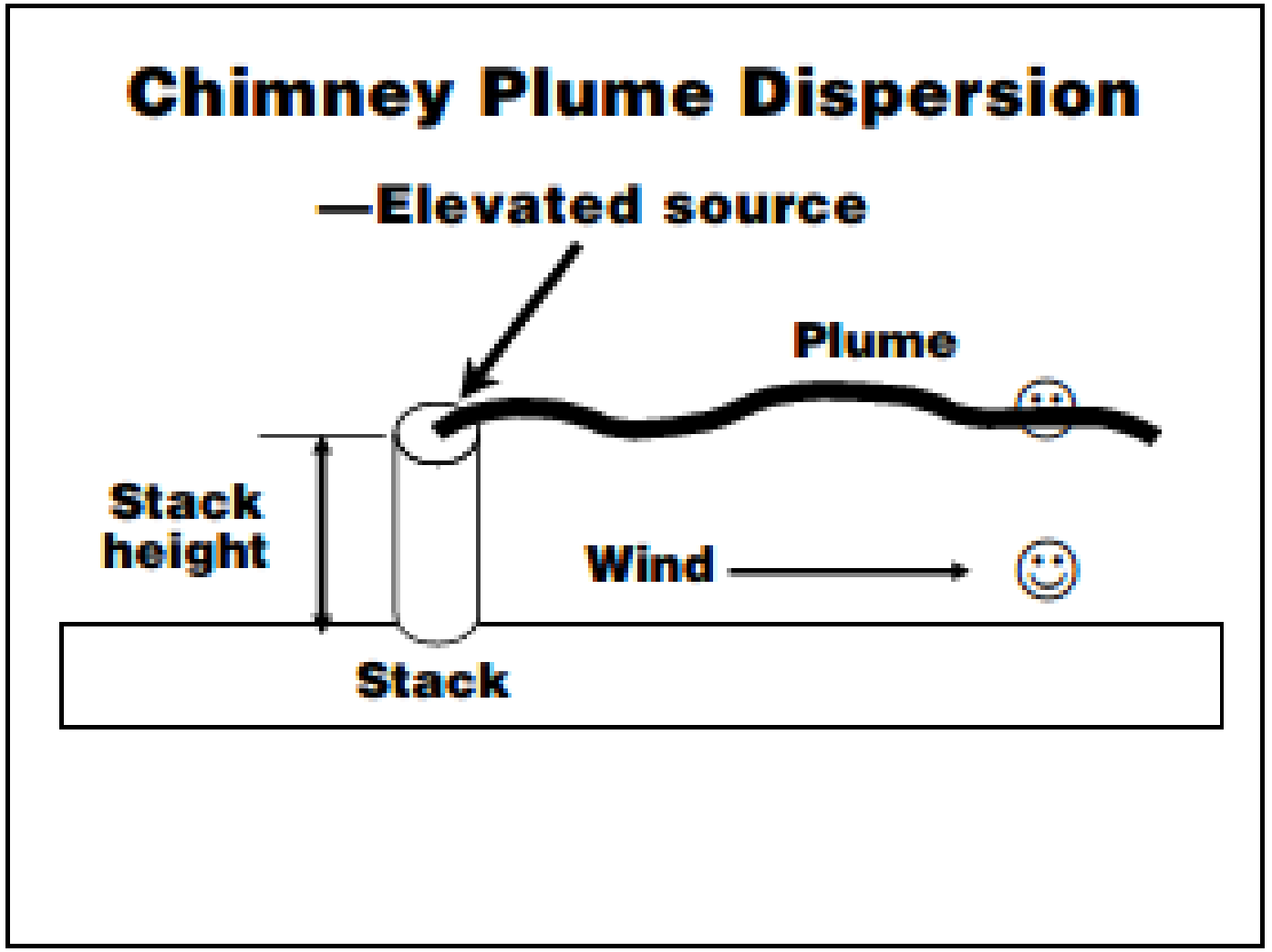
The vertical movement is neither encouraged nor hindered

- When air temperature increases with altitude an inversion occurs.
- The most common inversion type is radiation inversion and occurs when the earth's surface cools rapidly

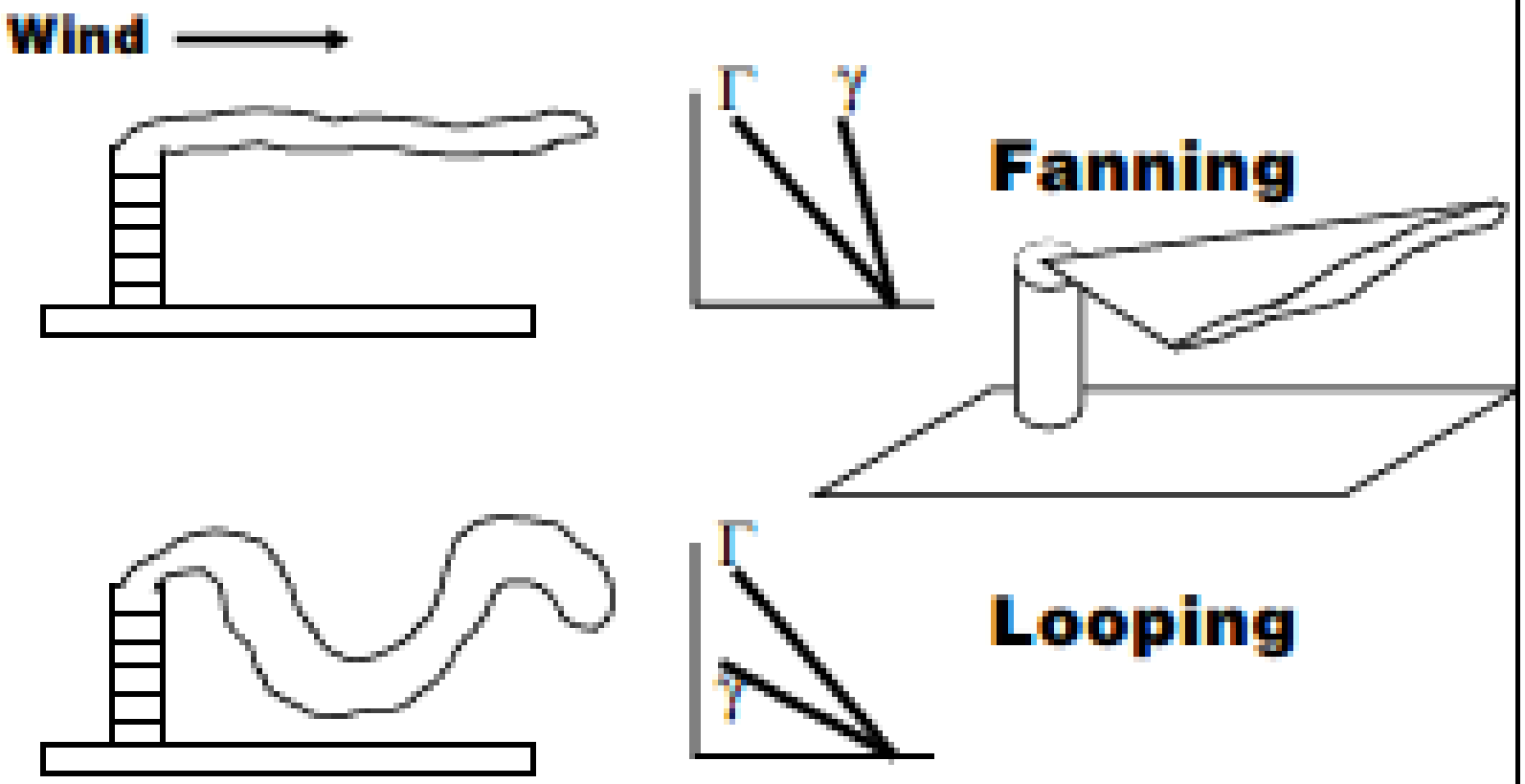


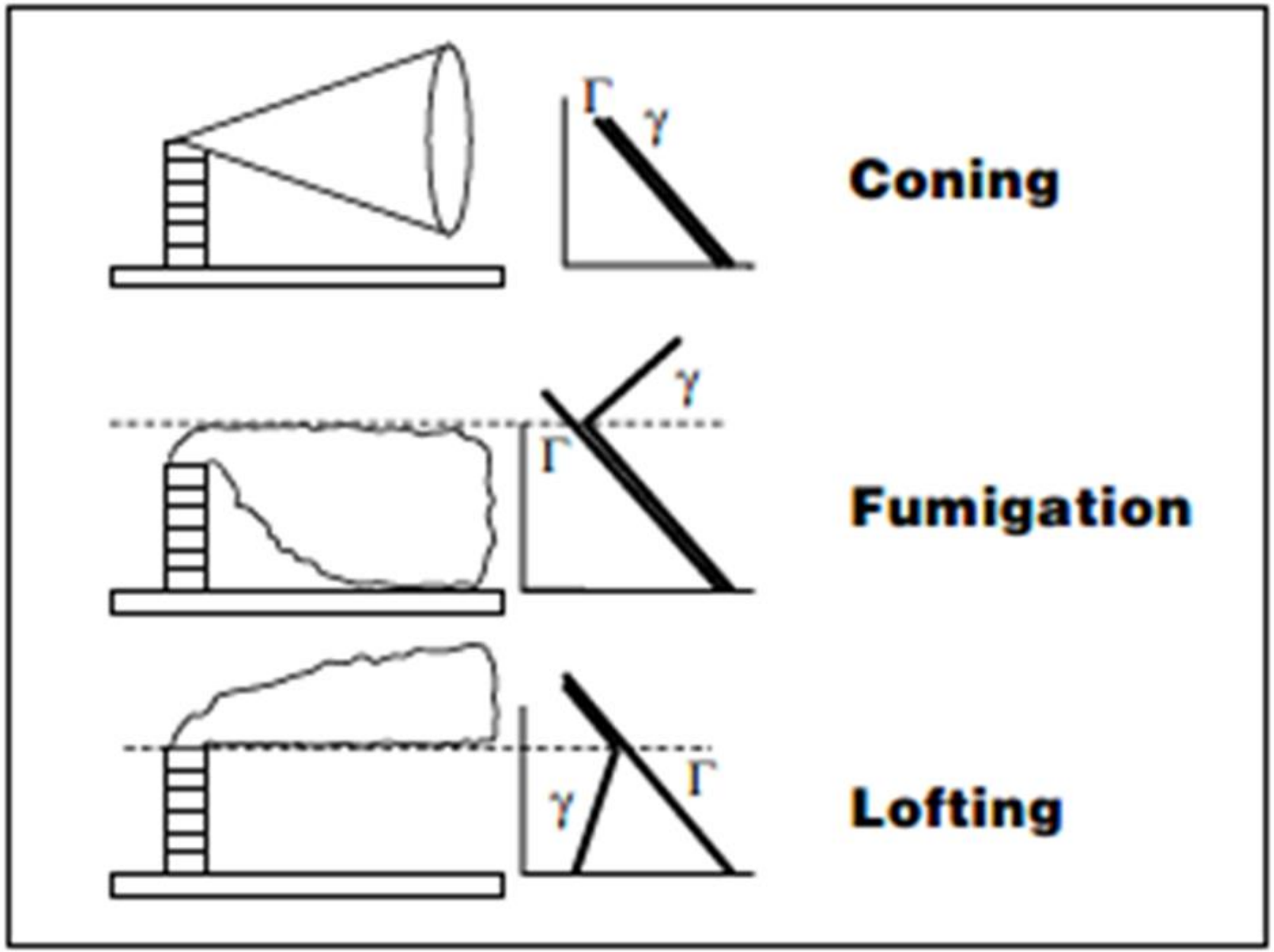

Almaty, Kazakhstan's largest metropolis
Smog

STABILITY AND PLUME BEHAVIOUR



Chimney Plume Types

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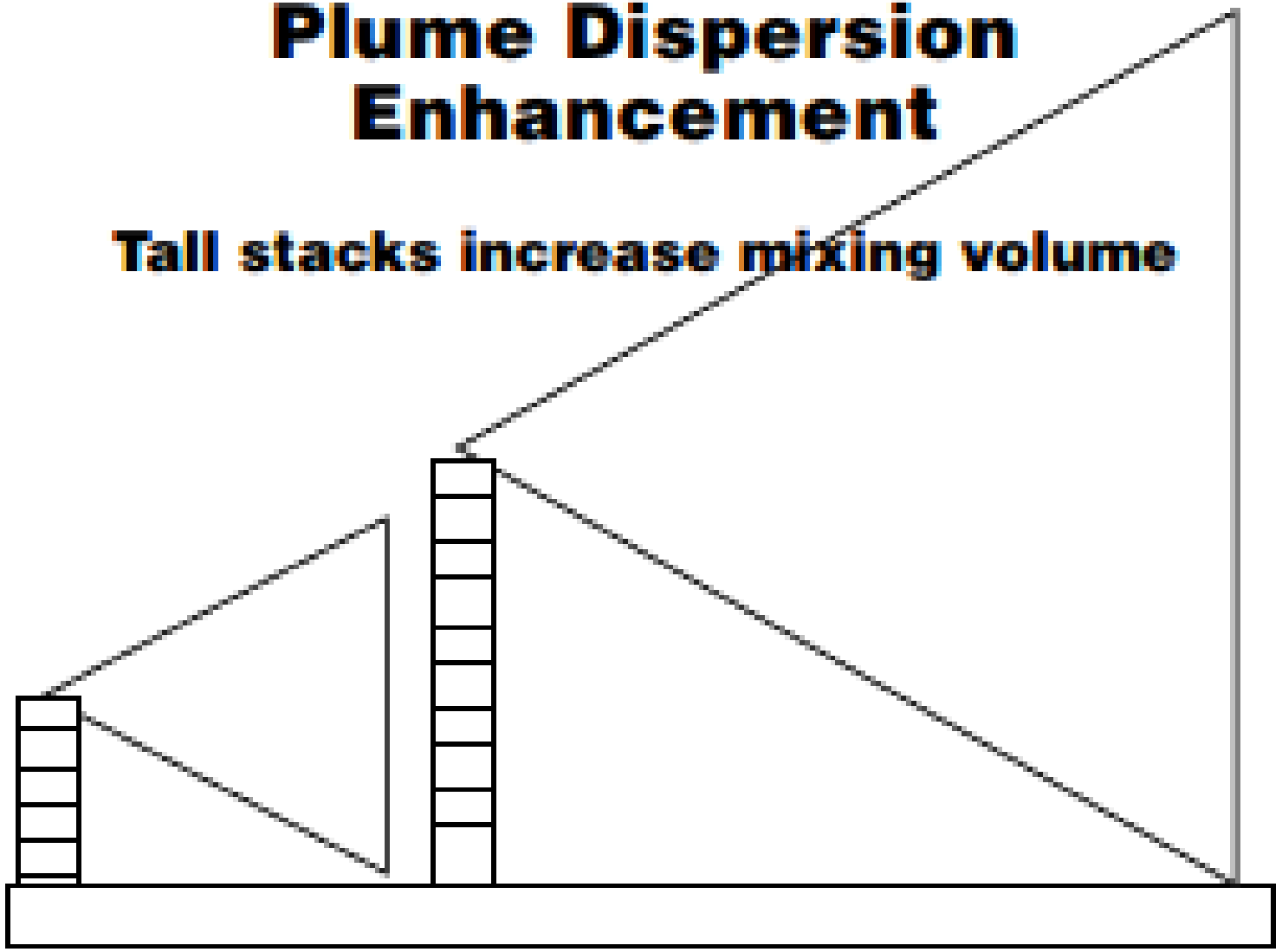
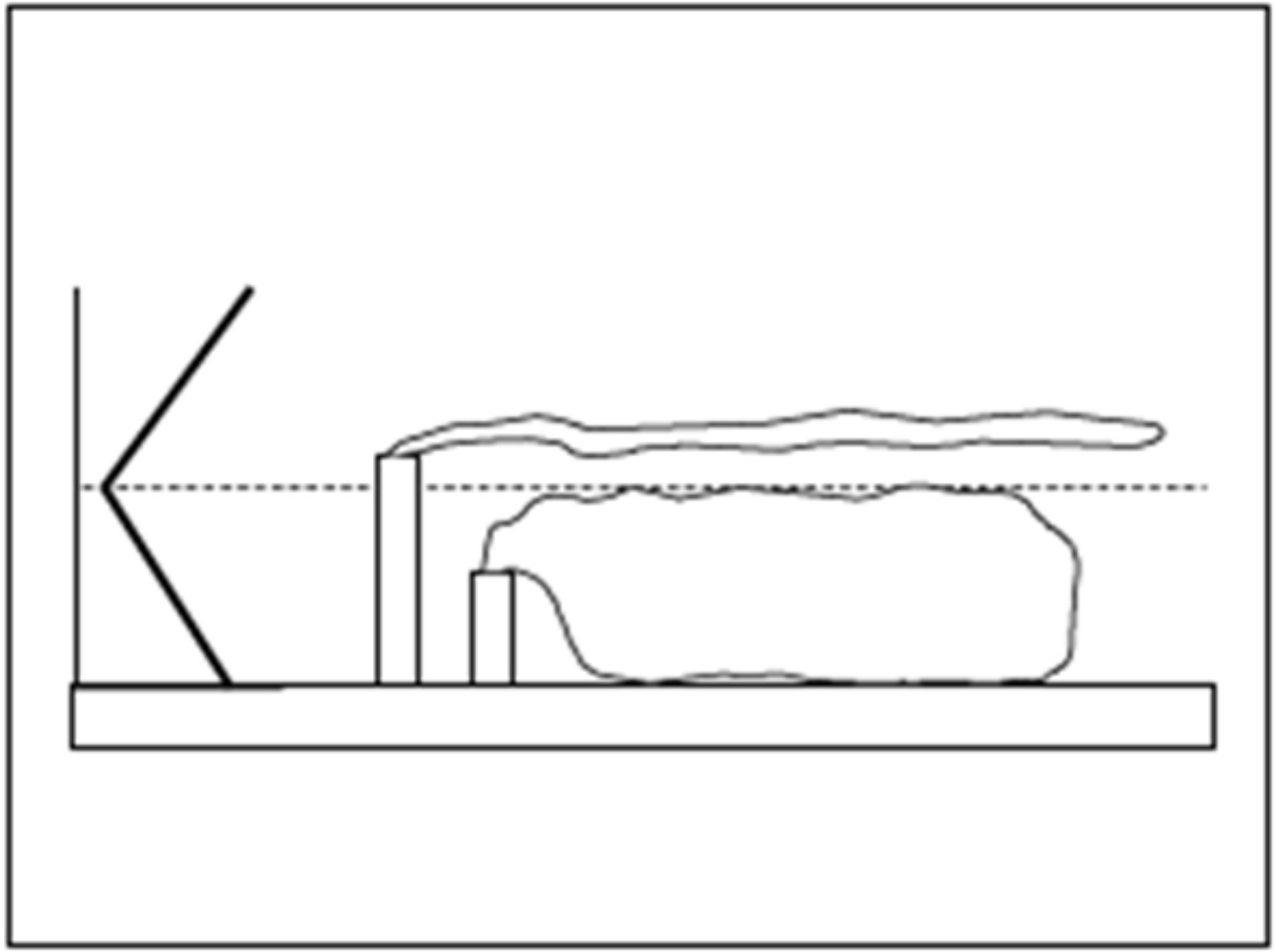
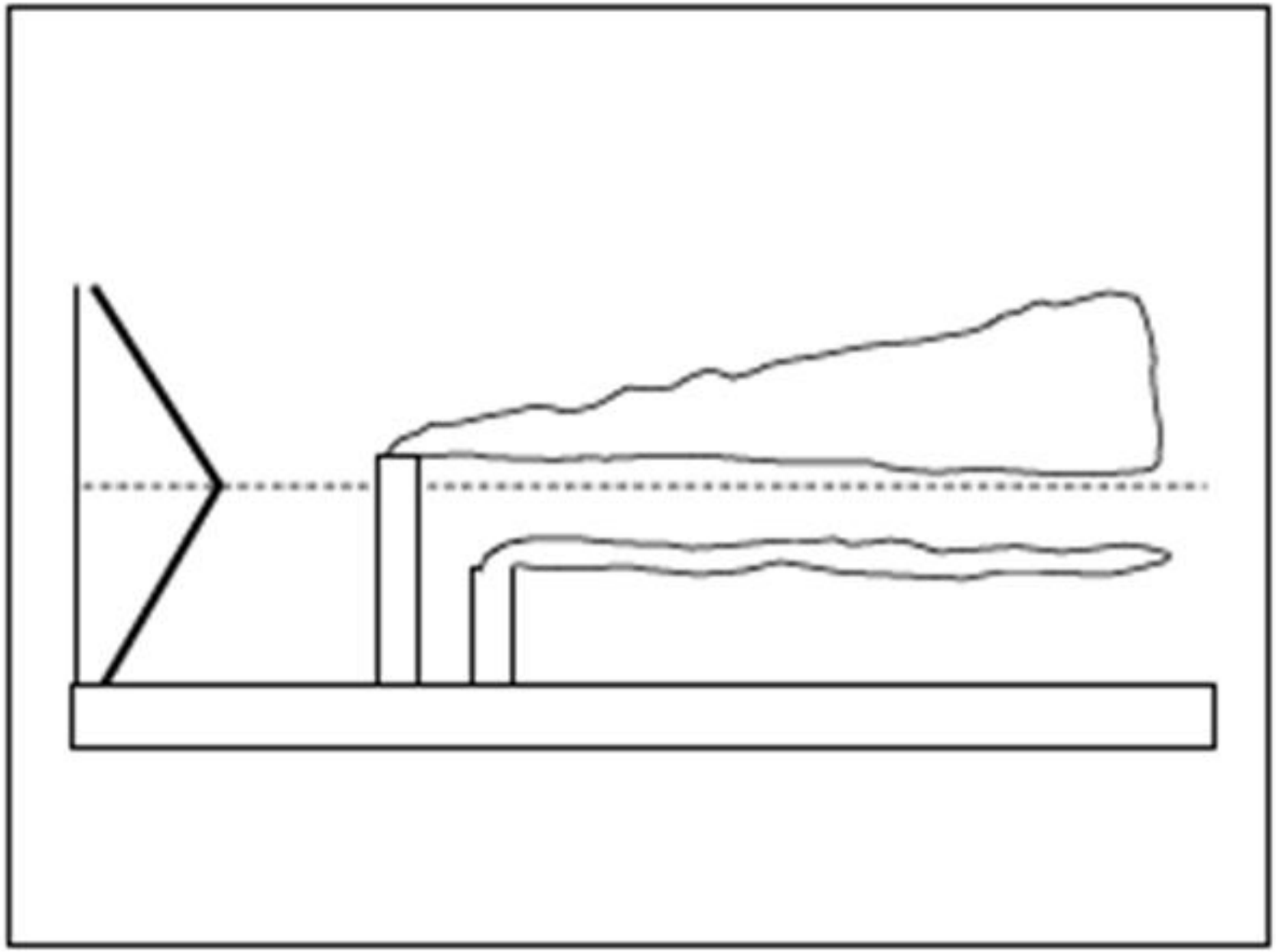
Lofting

Plume Dispersion Enhancement

Tall stacks increase mixing volume







Artificial Enhancement