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**Wind Rose, Plume Behaviour and
MMD**



**Air Pollution and Control
(Elective -I)**

Wind Rose Diagram

- The wind rose is the time honored method of graphically presenting the wind conditions, direction and speed, over a period of time at a specific location.
- Accurate estimation of the dispersion of pollutants in the atmosphere require a knowledge of the frequency distribution of wind directions as well as wind speed.

- To create a wind rose, average wind direction and wind speed values are collected at a site, at short intervals, over a period of time, e.g. **1 week, 1 month, 1 year or longer.**
- The collected wind data is then sorted by wind direction so that the percentage of time that the wind was blowing from each direction can be determined.

- Presented in a circular format, the wind rose shows the **frequency of winds blowing *from* particular directions over a particular period.**
- The length of each "spoke or segment" around the circle is related to the frequency that the wind blows from a particular direction per unit time.
- Each concentric circle represents a different frequency, starting from zero at the center to increasing frequencies at the outer circles.

- A wind rose plot may contain additional information, in that each spoke/segment is broken down into color-coded bands that show wind speed ranges.
- Wind roses typically use 16 cardinal directions, such as north (N), NNE, NE, etc., although they may be subdivided into as many as 32 directions.
- In terms of angle measurement in degrees, North corresponds to $0^\circ/360^\circ$, East to 90° , South to 180° and West to 270° .

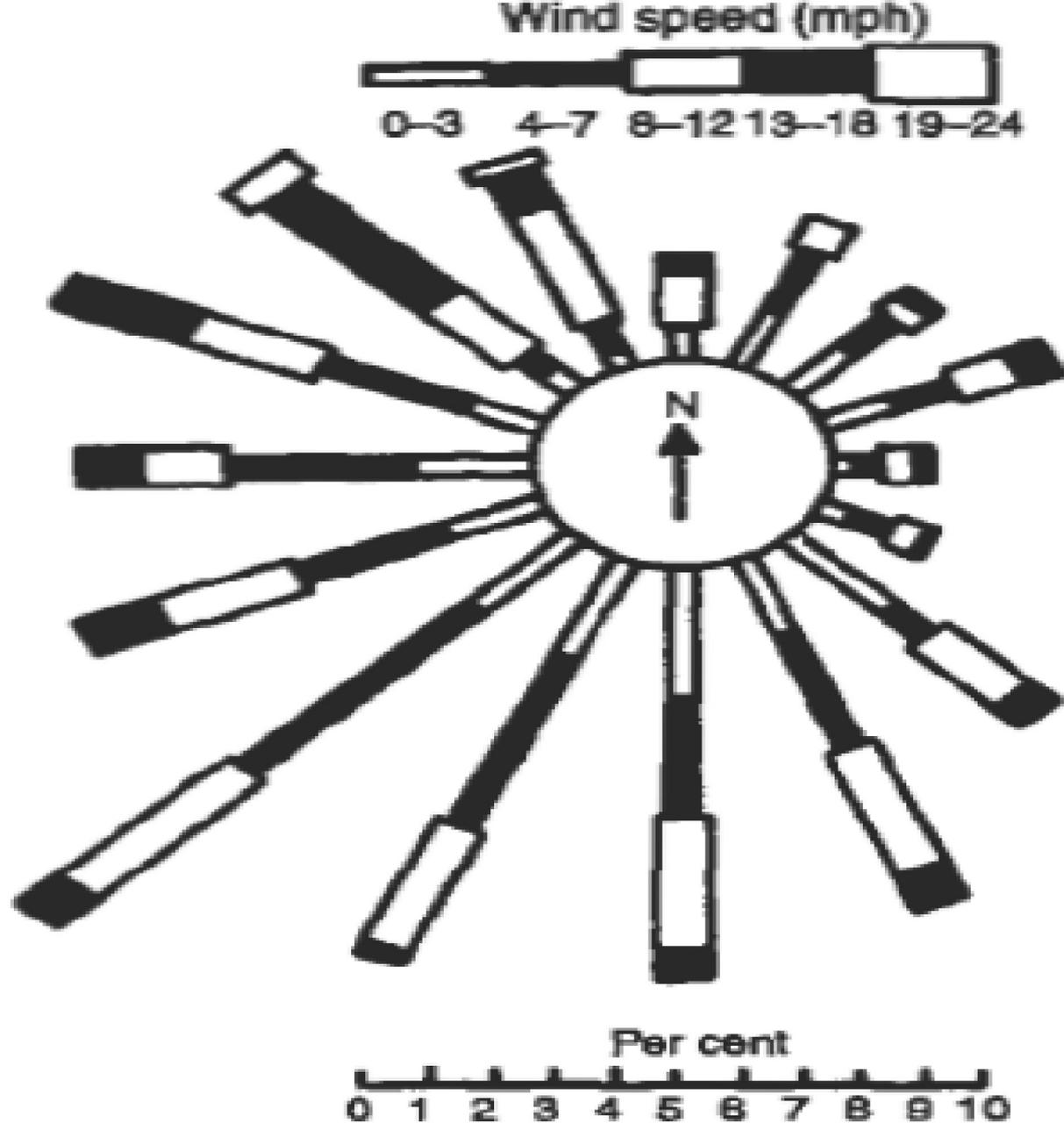
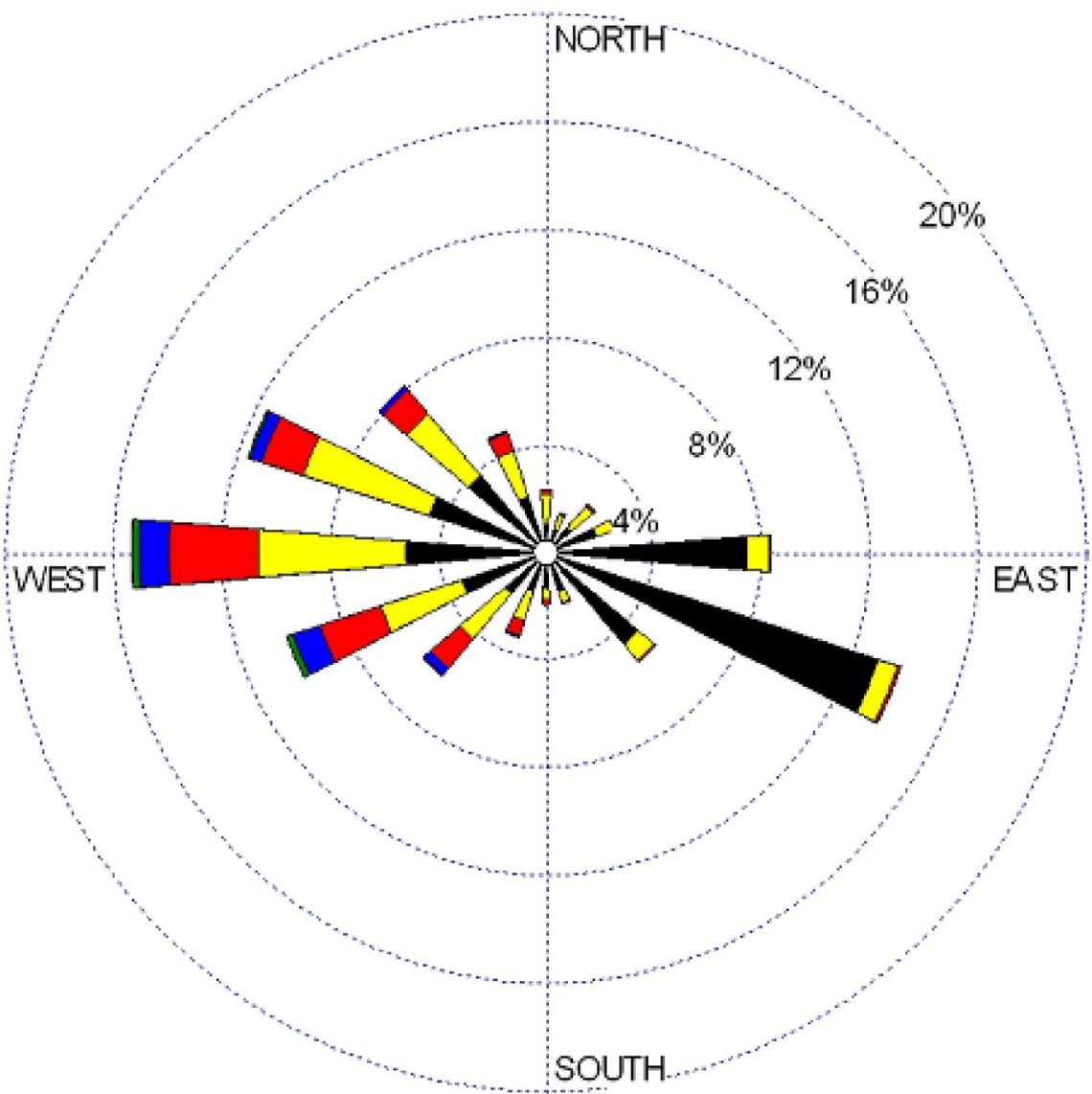


Figure 5. Typical wind rose.



WIND SPEED
(m/s)

- >= 10.0
- 8.0 - 10.0
- 6.0 - 8.0
- 4.0 - 6.0
- 2.0 - 4.0
- 0.0 - 2.0

Calms: 0.00%

Uses of wind rose

1. Sailors use wind rose.
2. Architects do, or should, use wind rose information for the siting of buildings and stadiums.
3. Wind-power "farms" (wind mills) do extensive wind rose type studies prior to erecting their wind turbines.
4. Also used for siting of industries in order to minimize impact of air pollution on neighboring cities

Why are these plumes so different?



Plume Behaviour

1. Looping Plume

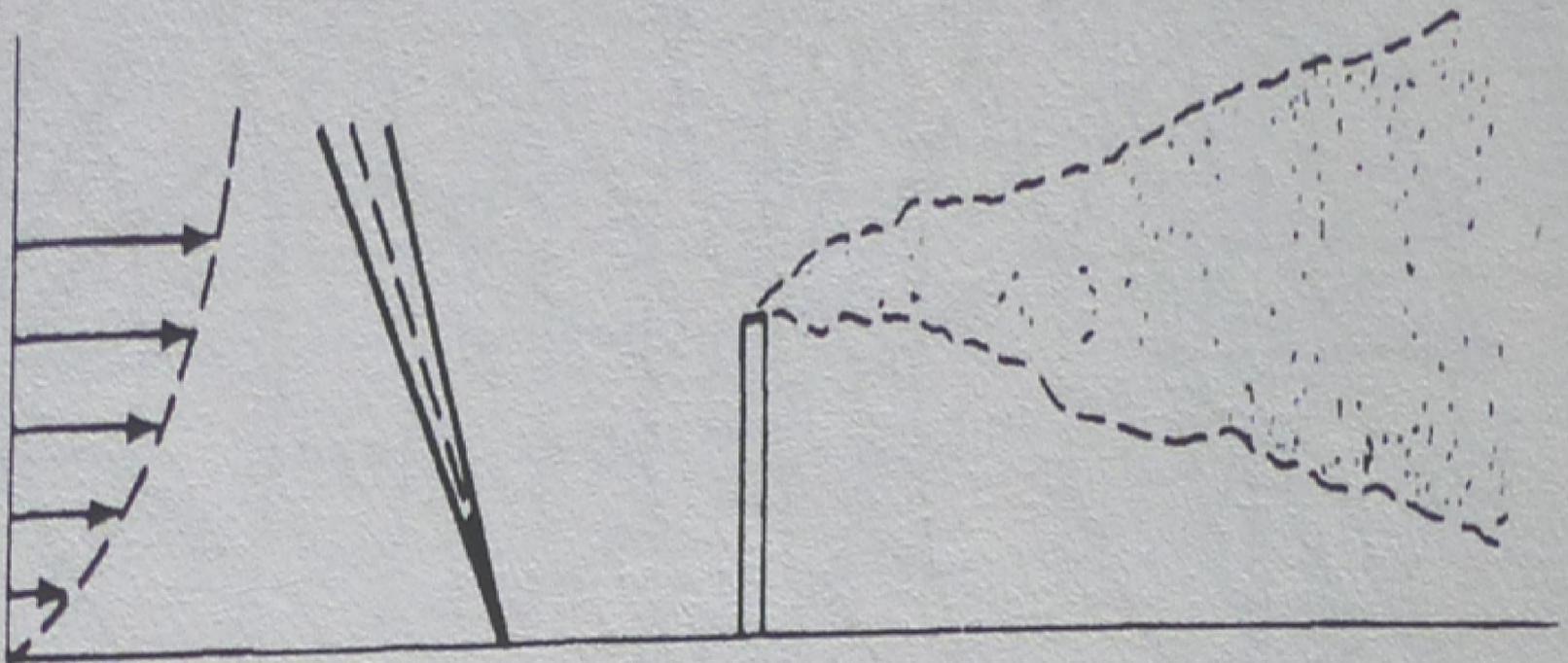
- High degree of convective turbulence
- Super adiabatic lapse rate -- strong instabilities
- Associated with clear daytime conditions accompanied by strong solar heating & light winds
- High probability of high concentrations at ground level close to stack.
- Occurs in unstable atmospheric conditions.



2. Coning Plume

- Stable with small-scale turbulence
- Associated with overcast moderate to strong winds
- Roughly 10° cone
- Pollutants travel fairly long distances before reaching ground level in significant amounts
- Occurs in neutral atmospheric conditions





(b)

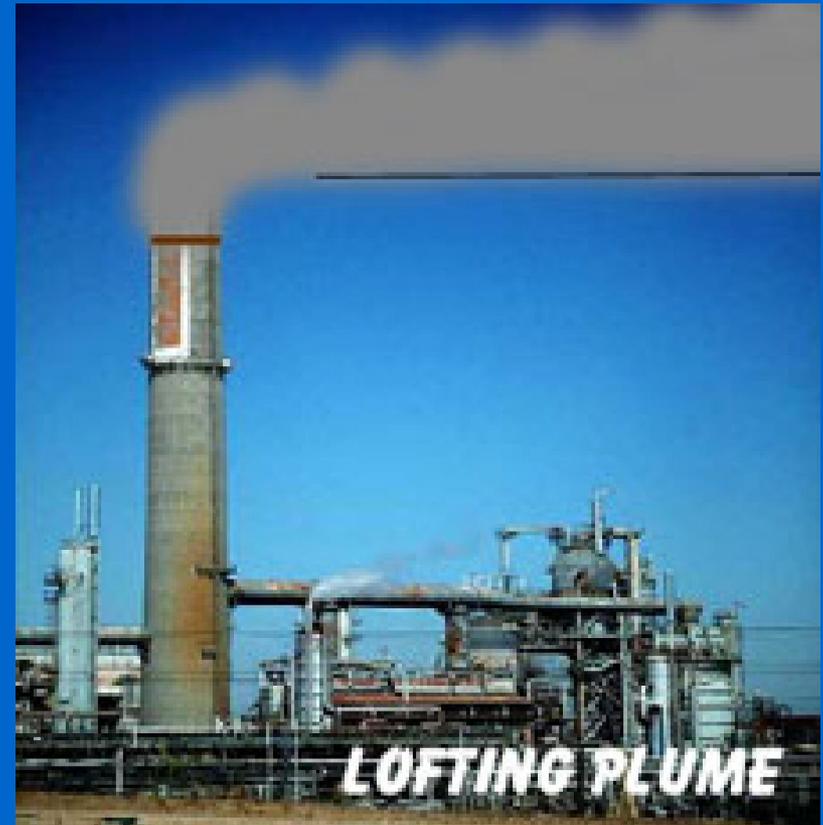
3. Fanning Plume

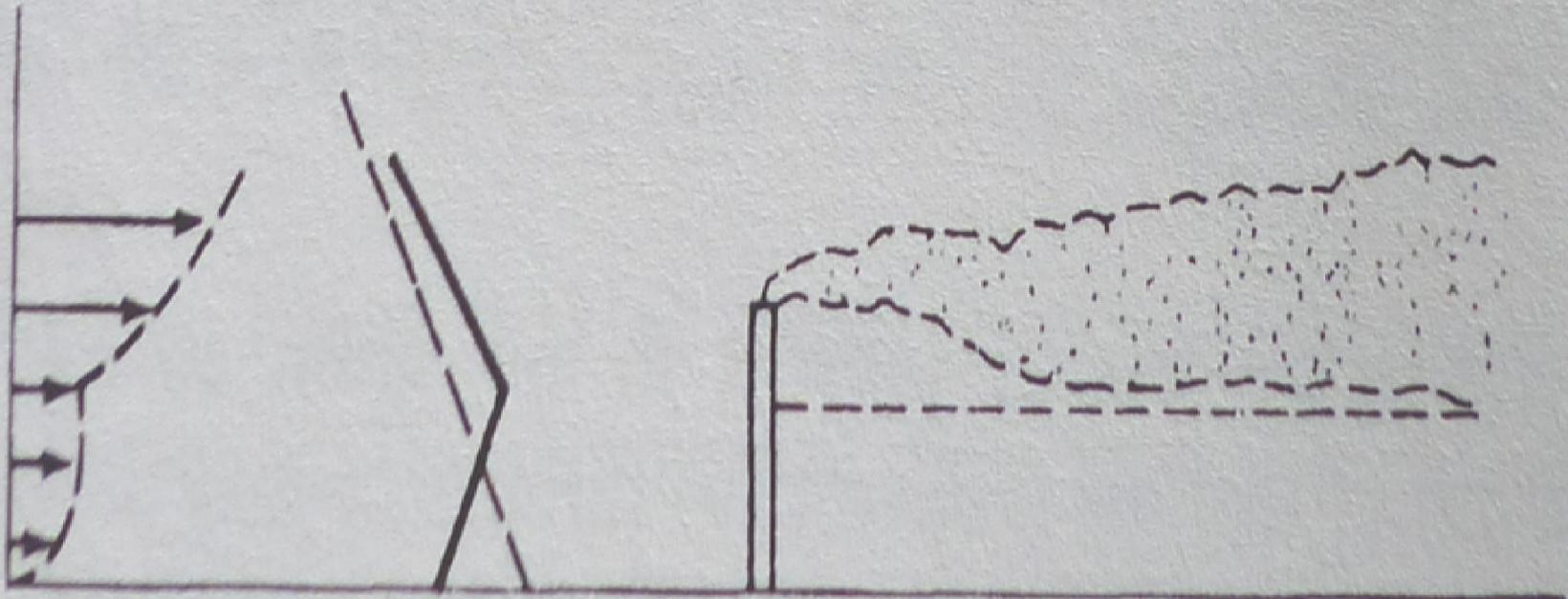
- Occurs under large negative lapse rate
- Strong inversion at a considerable distance above the stack
- Extremely stable atmosphere
- Little turbulence
- If plume density is similar to air, travels downwind at approximately same elevation



4. Lofting Plume

- Favorable in the sense that fewer impacts at ground level.
- Pollutants go up into environment.
- They are created when atmospheric conditions are unstable above the plume and stable below.





(e)

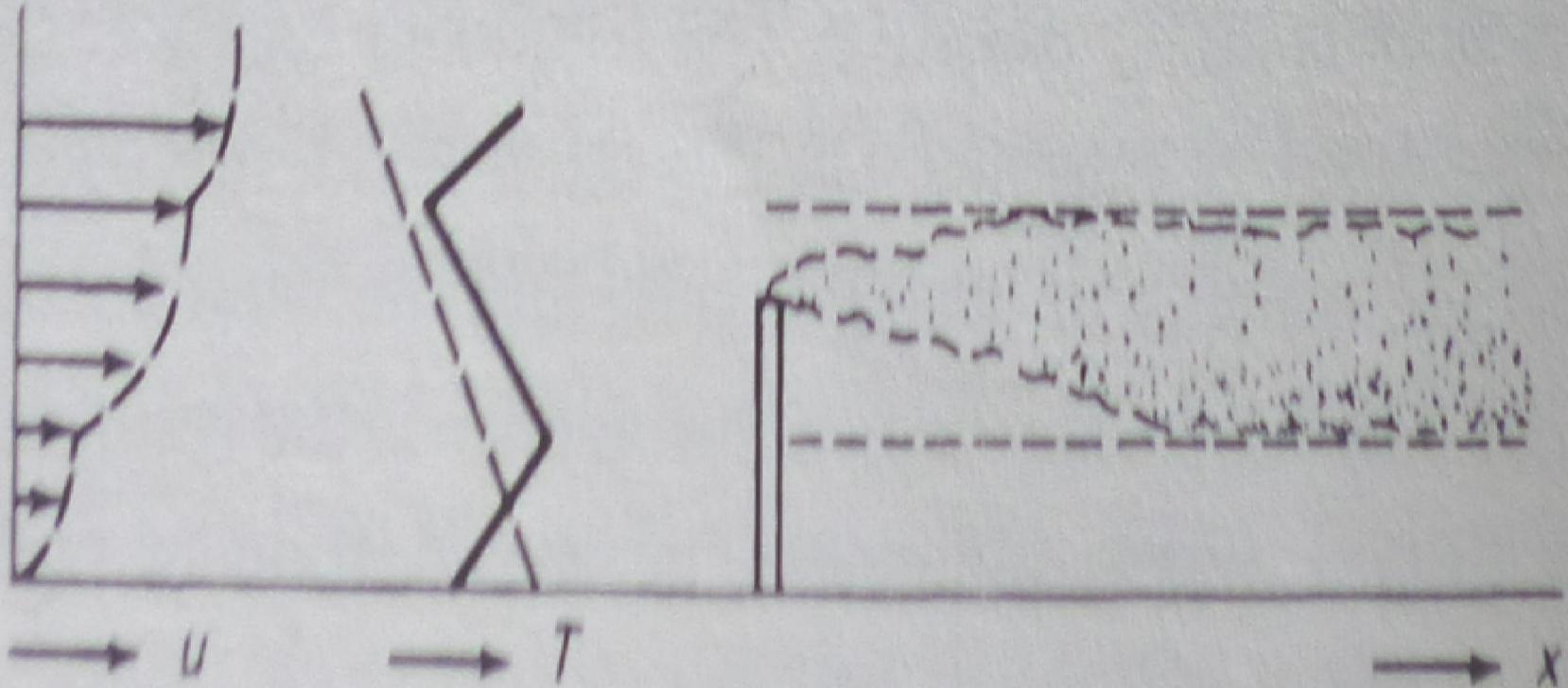
5. Fumigation

- Most dangerous plume: contaminants are all coming down to ground level.
- They are created when atmospheric conditions are stable above the plume and unstable below.
- This happens most often after the daylight sun has warmed the atmosphere, which turns a night time fanning plume into fumigation for about a half an hour.



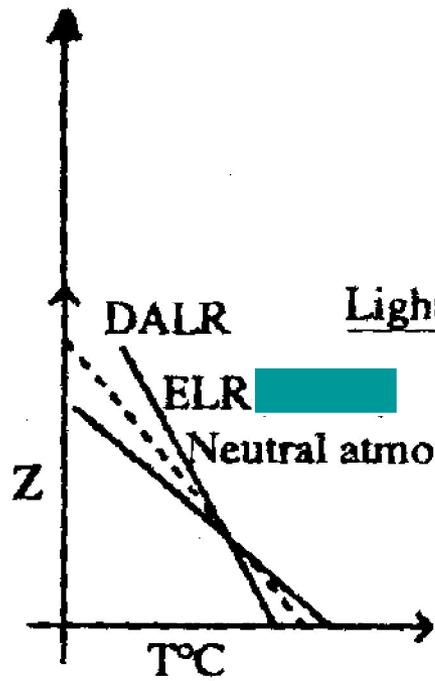
6. Trapping plume

- When inversion exists both below and above stack height, trapping results.
- The diffusion of pollutant is severely restricted to the layer between the two stable regions as shown in the figure.

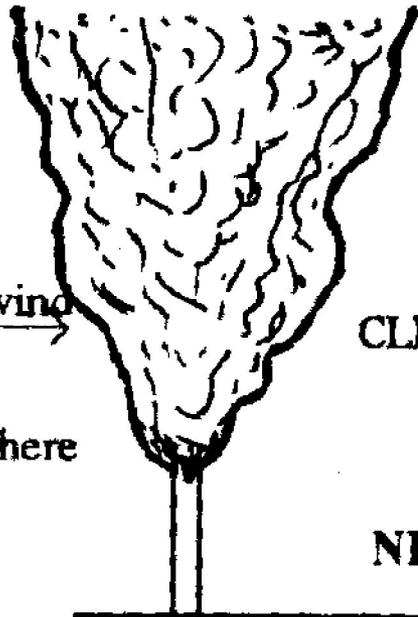


7. Neutral Plume

- It tends to rise vertically until it reaches air density similar to that of plume itself. It is often converted to coning if wind velocity is greater than 10 m/sec and when cloud cover blocks solar radiation.



Light wind



CLEAR SKIES IN NEUTRAL ATMOSPHERE

NEUTRAL PLUME



**Captured near Pandharpur
(Satara –Pandharpur road)**

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Maximum Mixing Depth (MMD)

- The dispersion of pollutants in the lower atmosphere is greatly aided by the convective and turbulent mixing that takes place.
- The vertical extent to which this mixing takes place depends on the environmental lapse rate which varies diurnally, from season to season and is also affected by topographical features.
- The depth of the convective mixing layer in which vertical movement of pollutants is possible, is called the maximum mixing depth (MMD).

- *The maximum mixing depth (sometimes called the mixing height) is obtained by projecting the dry adiabatic lapse rate line to the point of intersection with the atmospheric temperature profile*
- These profiles are usually measured at night or early in the morning.
- An air parcel at a temperature warmer than the existing ground level temperature rises and cools according to adiabatic lapse rate.
- *The level where its temperature becomes equal to the surrounding air gives the MMD value.*
- Urban air pollution episodes are known to occur when MMD is 1500 m or less.

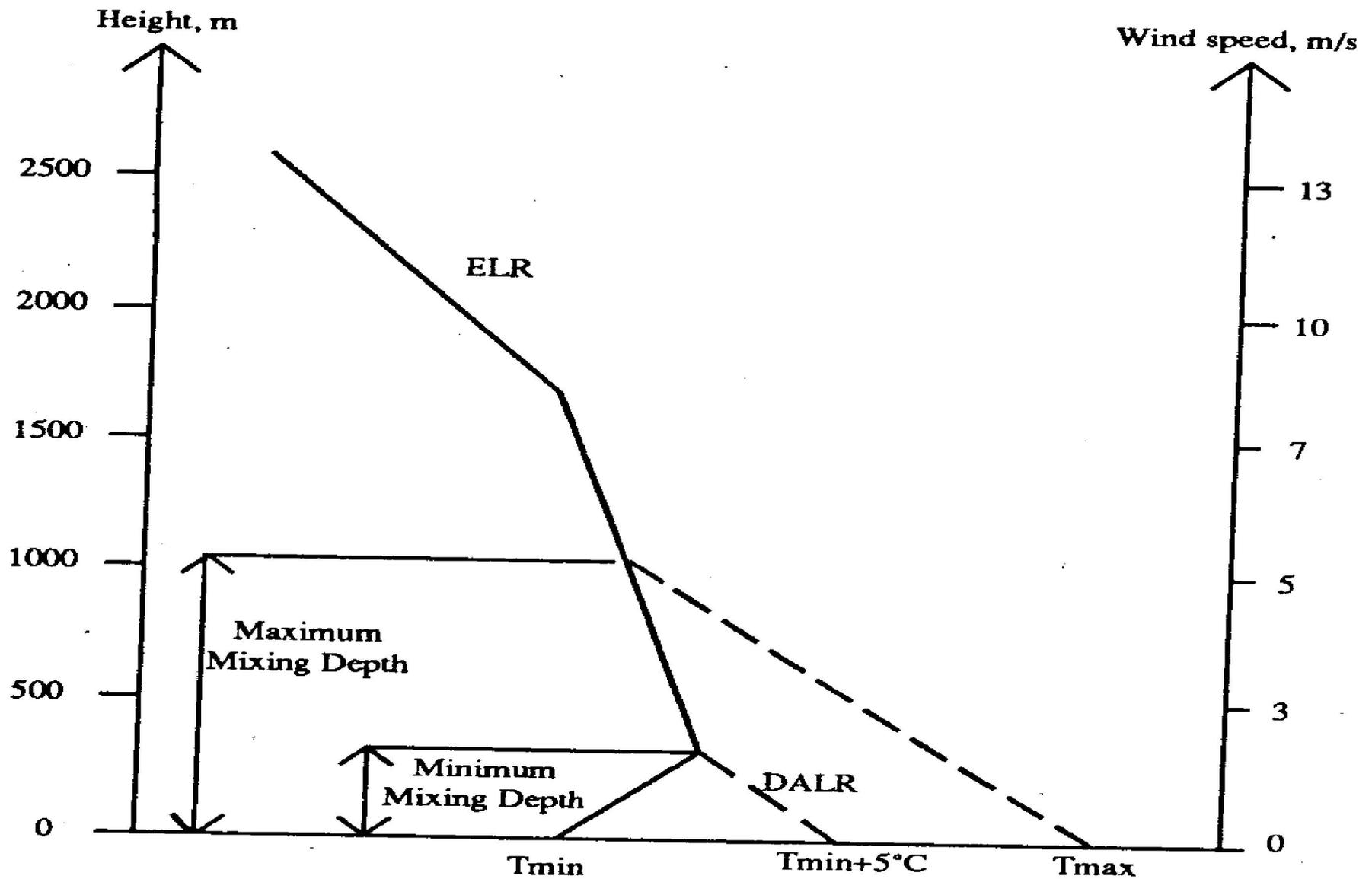
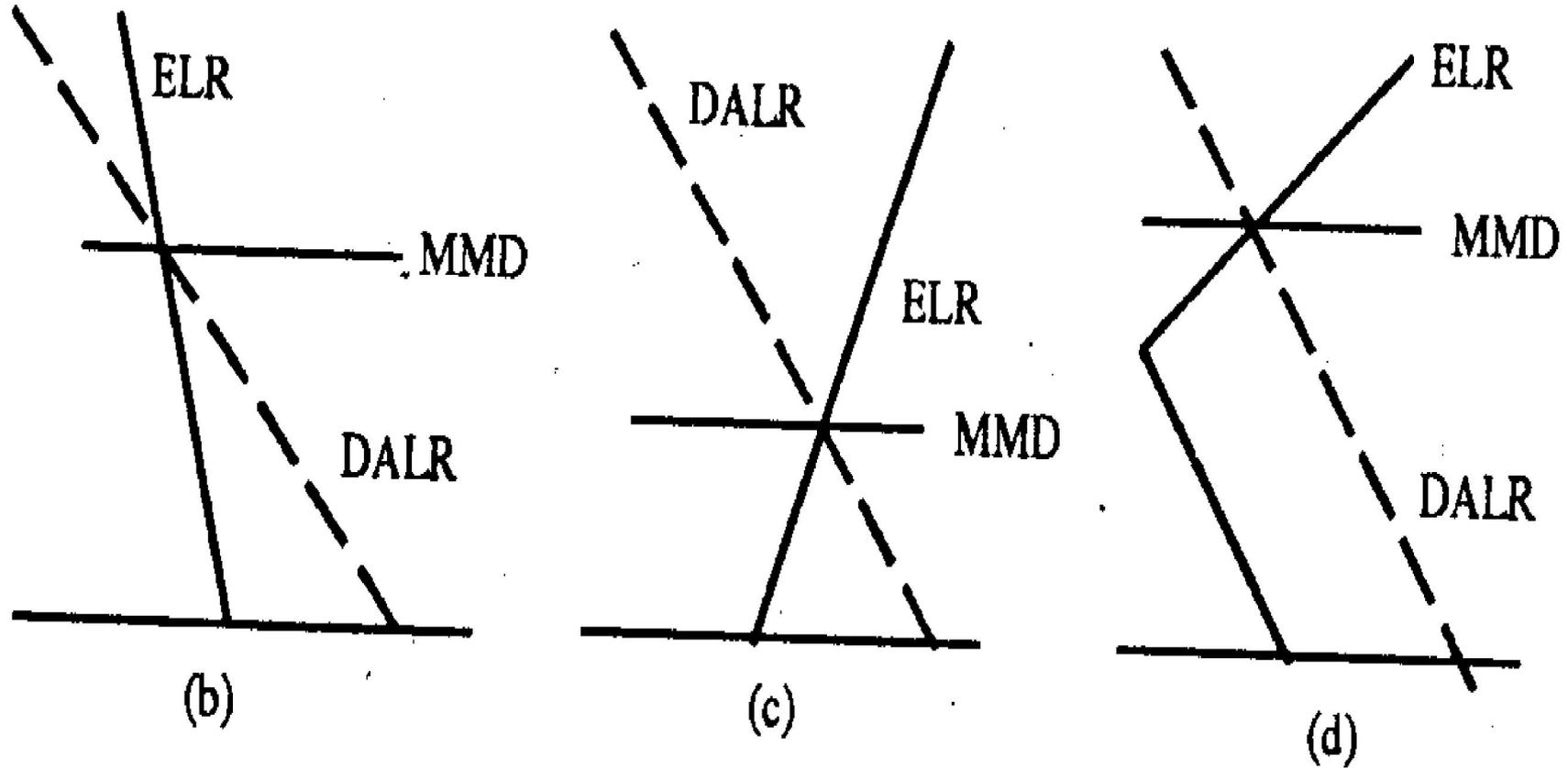


Fig.5.5(a) Computation of Mixing Depth in a Typical Environment

MMDs for different lapse rate profiles



**Fig.5.5(b) (c) (d) : Maximum Mixing Depth
in Different Environments**

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Summary....of MMD

- Parcel heated by solar radiation at earth's surface
 - Rises until temperature $T' = T$
 - $T' =$ particle's temp
 - $T =$ atmospheric temp
 - Achieves neutral equilibrium, no tendency for further upward motion
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DETERMINATION OF MAXIMUM MIXING HEIGHT

- The following steps can be used to determine the maximum mixing height for a day from a temperature profile:
 1. Plot the temperature profile (ELR), if needed.
 2. Plot the maximum surface temperature for the day on the graph for morning temperature profile.
 3. Draw a dry adiabatic line ($-1^{\circ}\text{C}/100\text{m}$) from the point of maximum surface temperature to the point where it intersects the morning temperature profile.
 4. Read the corresponding height above ground at the point of intersection obtained in step 2. This is the maximum mixing height for the day.

Practice problem (MMD)

Calculate the maximum mixing height from the following early morning temperature data given below:

The maximum surface temperature for the day was 15°C .

(Hint:- Follow steps given in previous slide. From tabular values plot ELR and 15°C is air parcel temp in contact with surface apply DALR to it)

Height (m)	0	250	350	450	550	650
Temperature ($^{\circ}\text{C}$)	9.5	12.2	15.1	15.6	16.2	16.5

- A **radiosonde** (*Sonde* is French for *probe*) is a unit for use in weather balloons that measures **various atmospheric parameters** and transmits them to a fixed receiver.

Radiosondes may operate at a radio frequency of **403 MHz or 1680 MHz** and both types may be adjusted slightly higher or lower as required.

- A **rawinsonde** is a radiosonde that is designed to only measure wind speed and direction. Rawinsondes are usually referred to as **Radiosondes**.

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MMD problems

Objective Questions

- Q1. Accurate estimation of the dispersion of pollutants in the atmosphere require a knowledge of the _____ of wind directions as well as _____.
- Q2. _____ are important for fixing location of new industries.
- Q3. Most dangerous type of plume is _____.
- Q4. When inversion exists both below and above stack height, _____ results.
- Q5. _____ is, at which temperature of air parcel and ambient air becomes equal at particular height.
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Theory Questions

Q1. Write detailed note on Plume Behaviour with neat sketches.

Q2. What is Maximum mixing depth?
Explain how do you determine the same?

Q3. Explain in detail wind rose construction and its use.

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