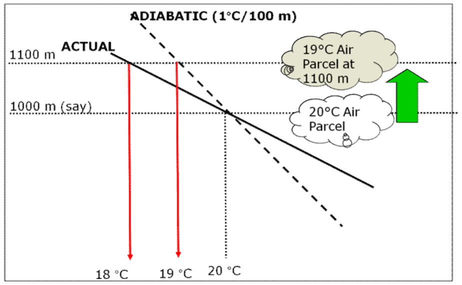
Lecture 4

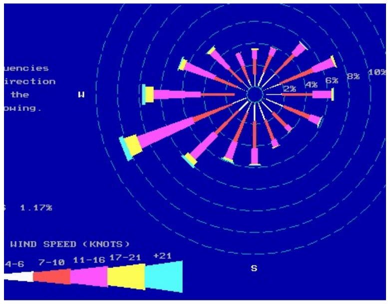
Air Quality:

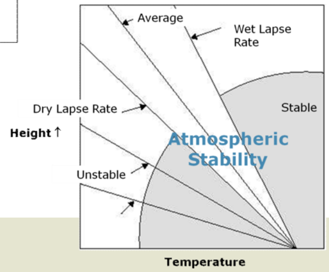
Measurement Methods, & Effect of Meteorology on Pollutants Dispersion

Harish C. Phuleria
CESE, IIT Bombay

Email: phuleria@iitb.ac.in

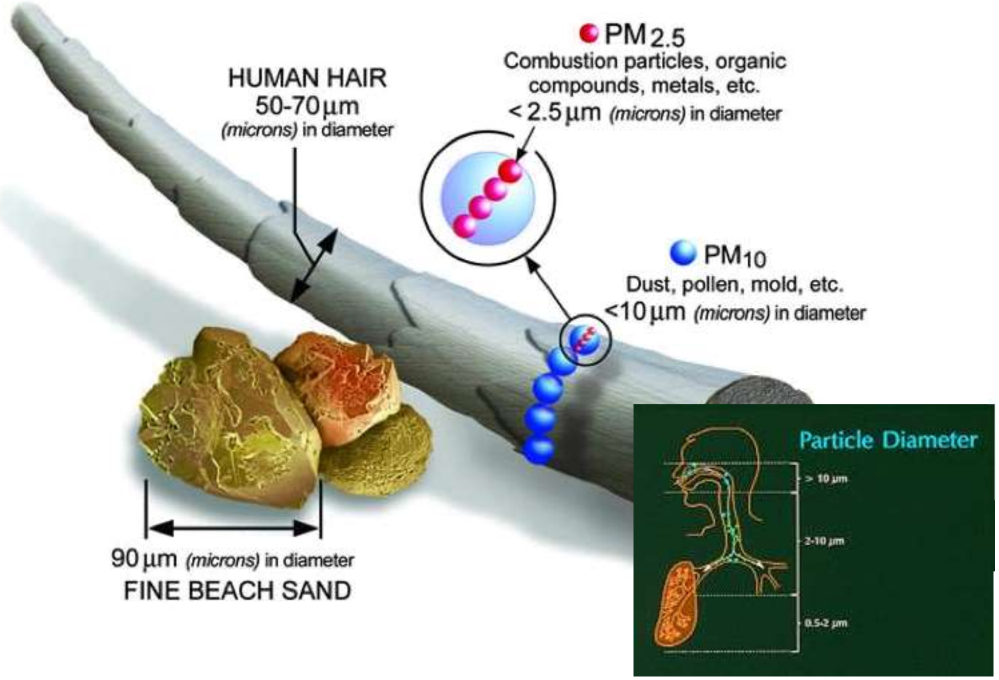


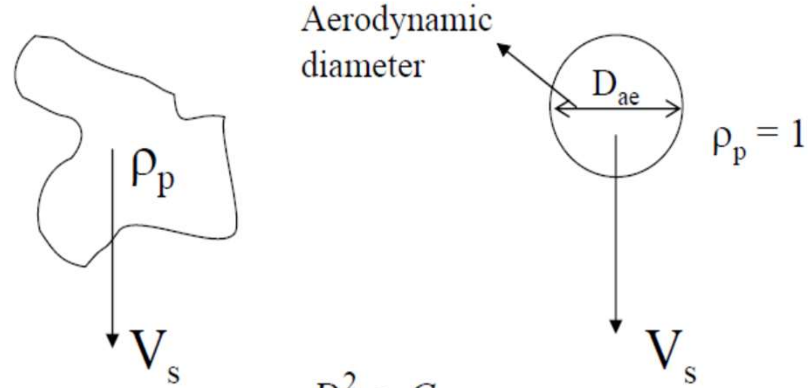




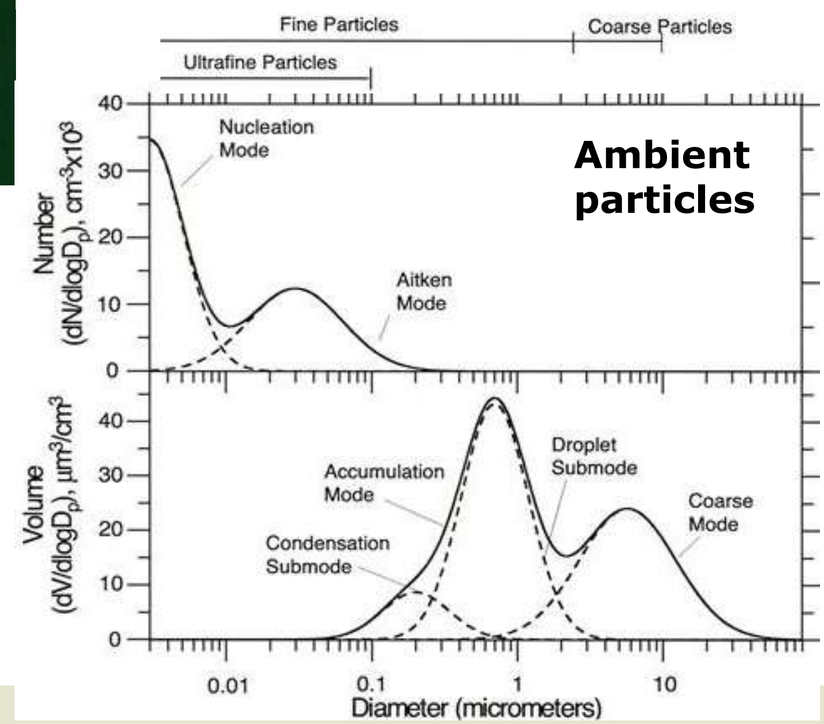
Recap 1

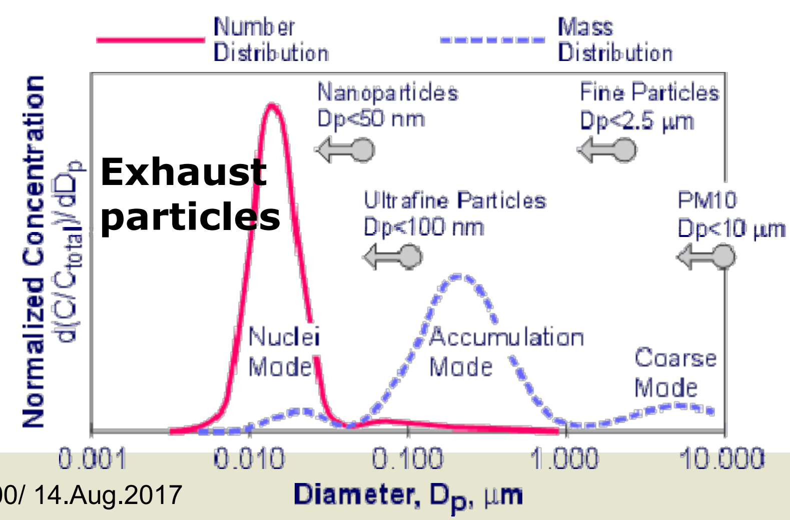
$PM_{2.5}$ / PM_{10} : Mass concentration of all particles having **aerodynamic diameter** $\leq$ 2.5 / 10μm



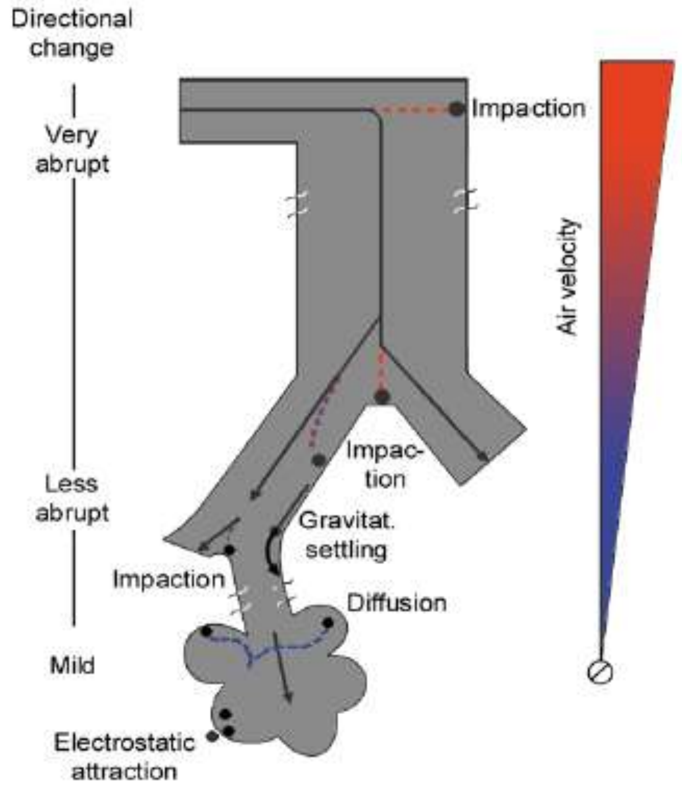


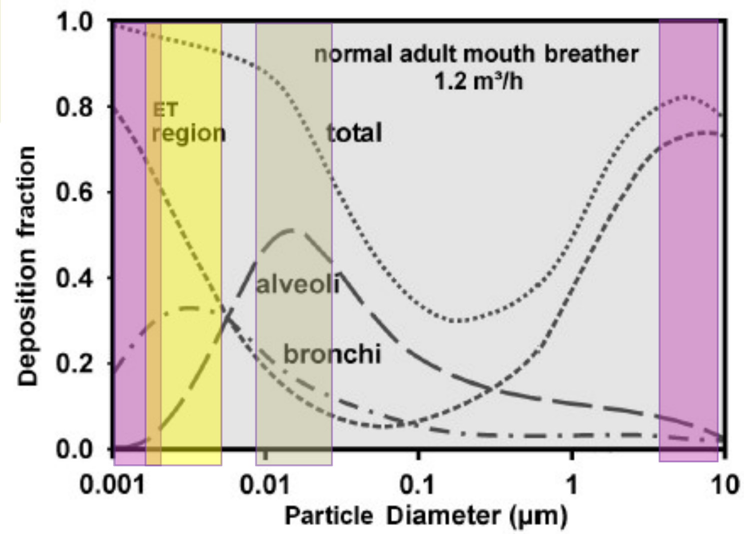
$$V_s = \frac{D_p^2 \rho_p C_c g}{18\eta}$$

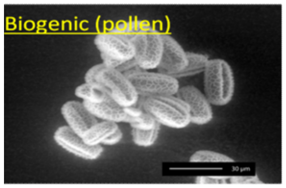


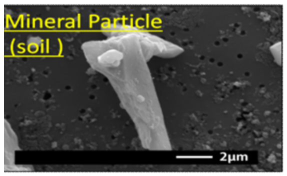


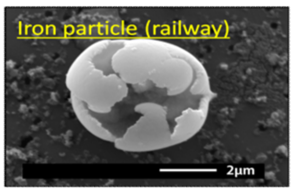
Recap 2

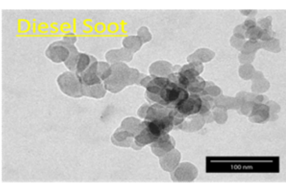


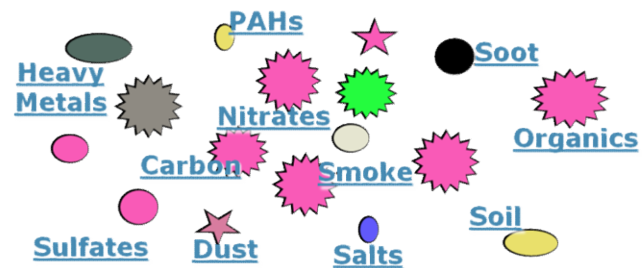




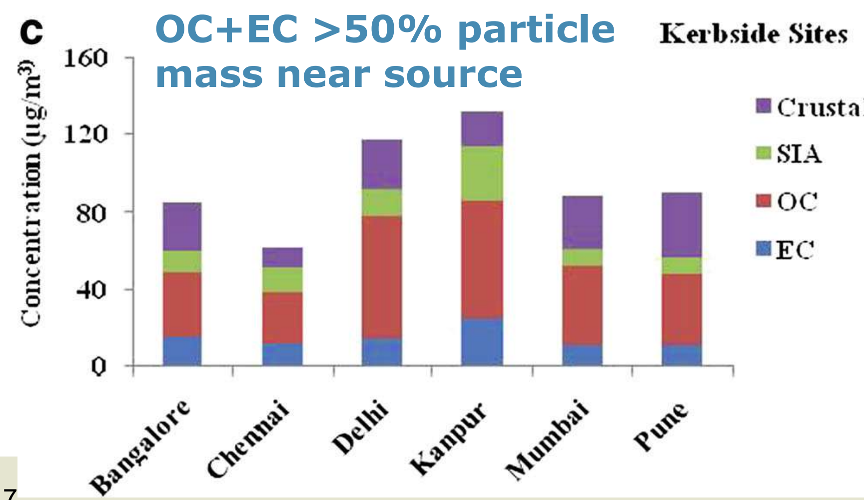








OC+EC >50% particle mass near source



Complex Mixture

- **Bulk composition:** EC, OC, Nitrate, Sulfate, Ammonium, dust
- **Trace constituents:** Heavy metals, PAHs, …

Today's Learning Objectives !

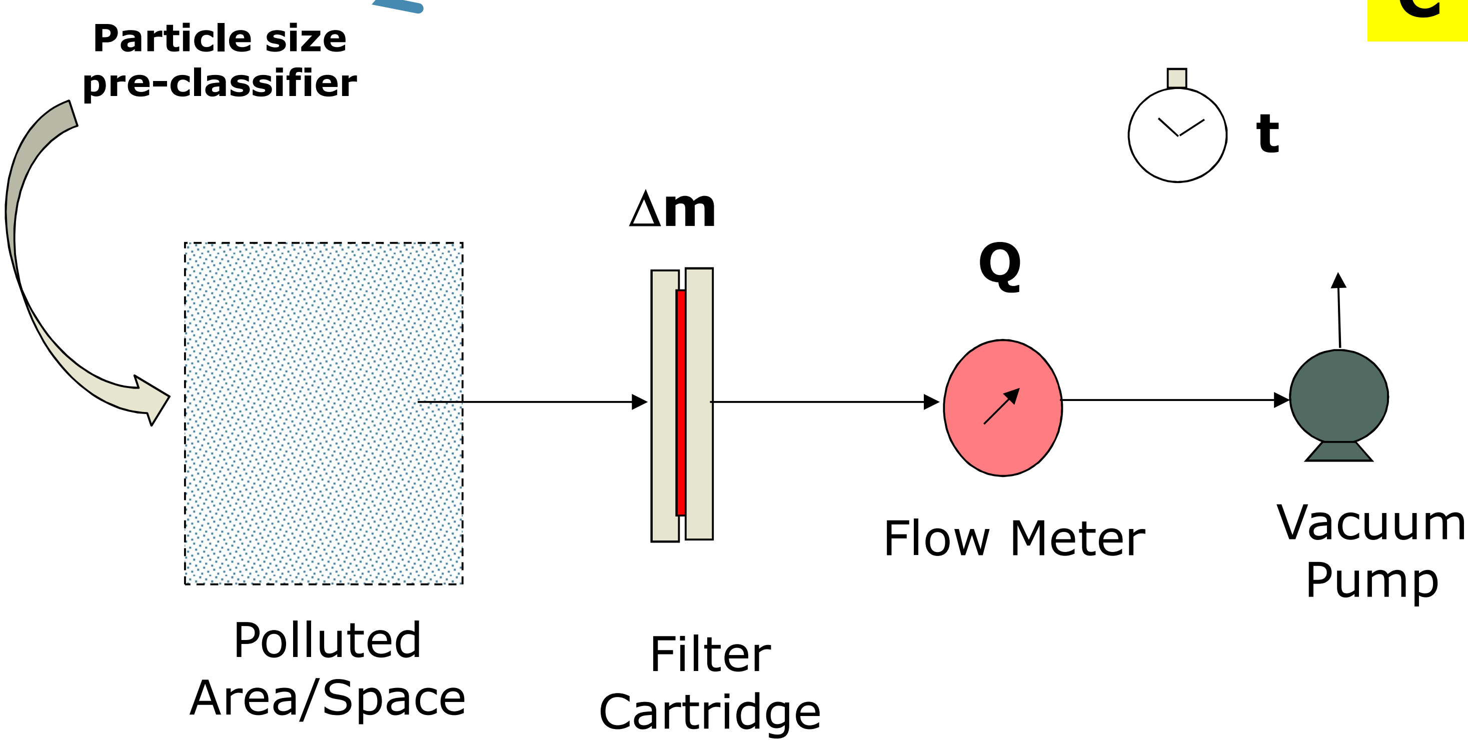
- To learn about monitoring methods and thus able to quantify pollutants' concentrations

- To explain effects of meteorology and the physics of dispersion of pollutants in the atmosphere

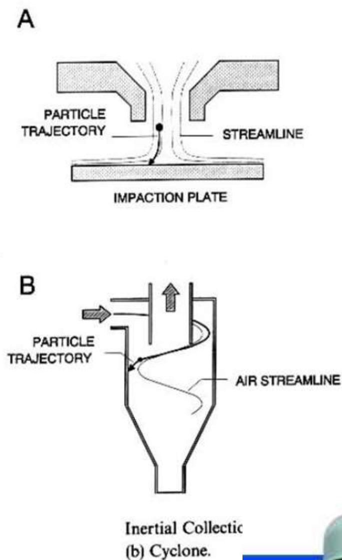
Quantifying pollutants: Particle mass concentration (PM$_{10}$/PM$_{2.5}$)

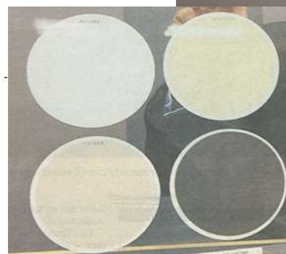
- How do you measure the mass concentration of PM ?

$$C = \Delta m / Q.t$$



Particle mass measurements





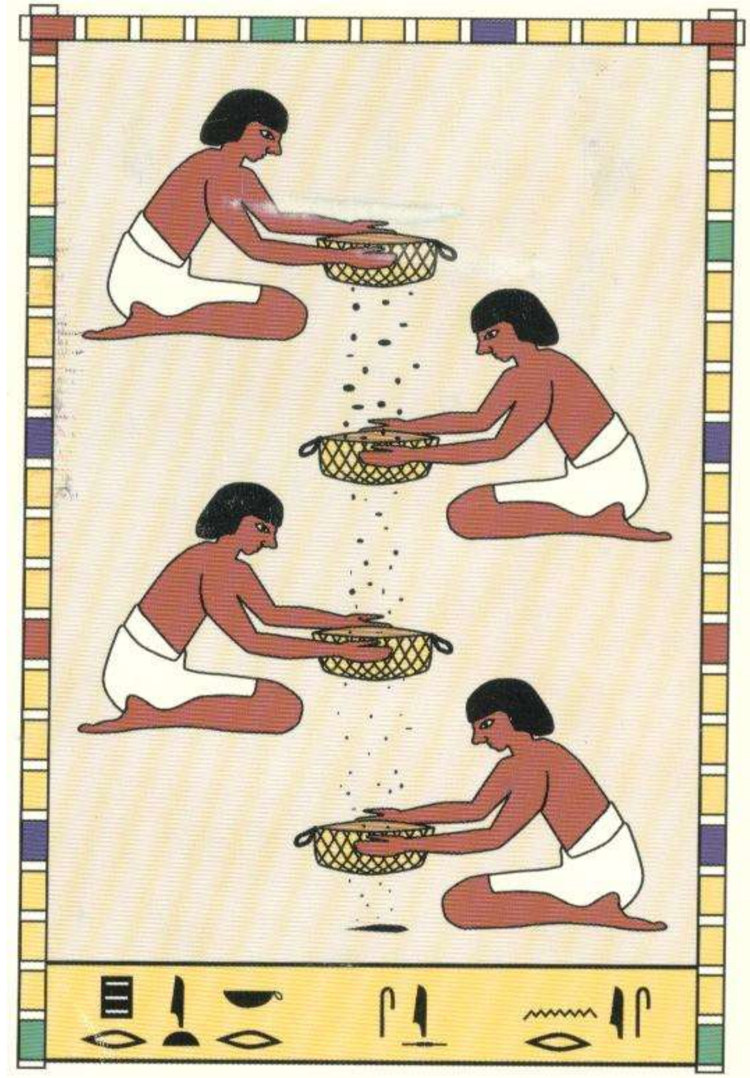
Clean room weighing facility

Ambient air monitoring station

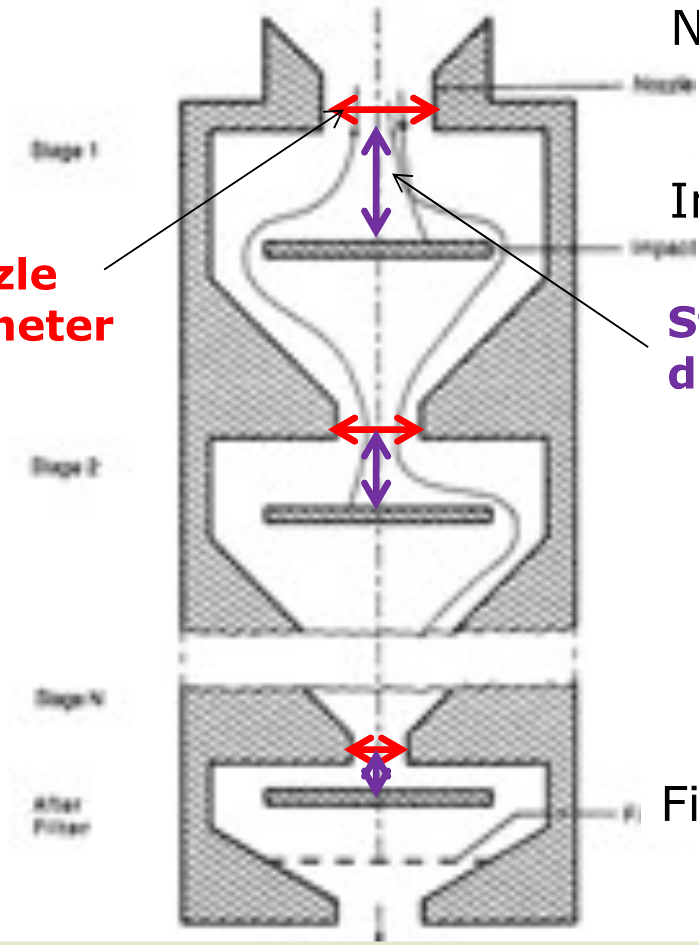
- Filter substrates are collected using impactors/cyclones (for desired size) and designed flow rate (with a suction pump)
- Collected filters are conditioned in laboratory & weighed with precision microbalance

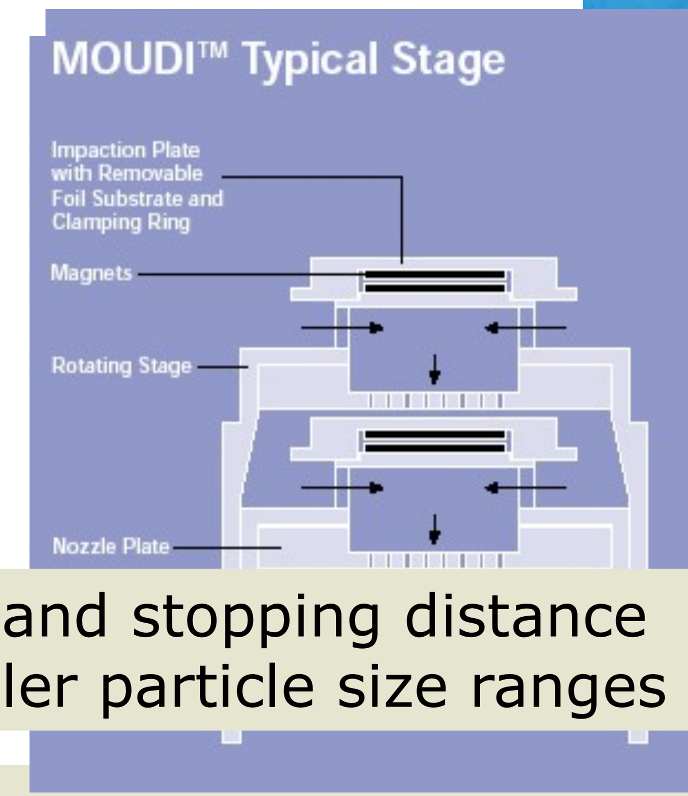
Sizing of Particles

- Inertial Impactors
  - Mass based (> 56 nm)
- Optical Particle Counters
  - Number based (> 400 nm)
- Electrical Mobility
  - Sizing (> 6 nm)
  - Counting (Condensation Particle Counters or Electron microscopy)



Particle sizing: MOUDI
(Micro-Orifice Uniform Deposit Impactor)

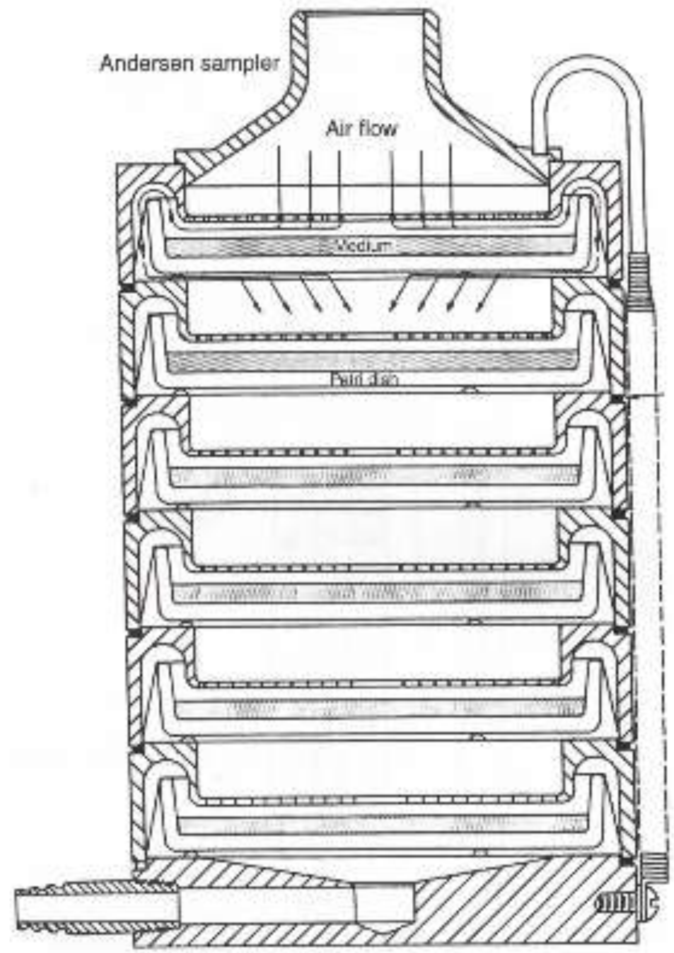




Successively nozzle diameter and stopping distance are decreasing to collect smaller particle size ranges !!!

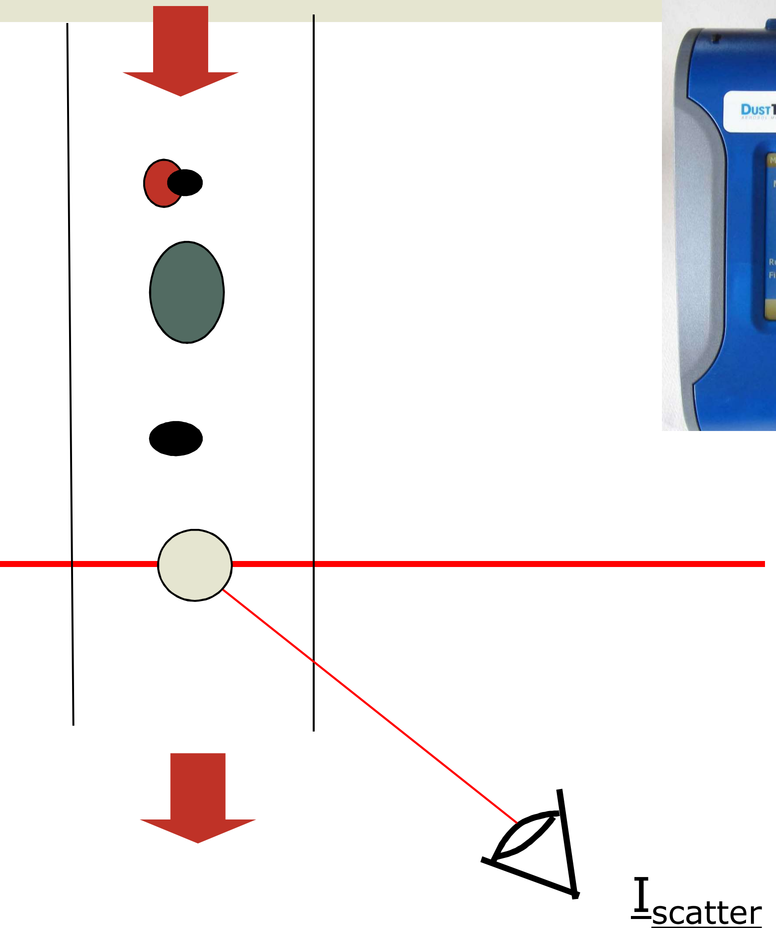
Particle (biological) sizing:
Anderson impactor

Anderson six-stage viable impactor



www.thermoscientific.com

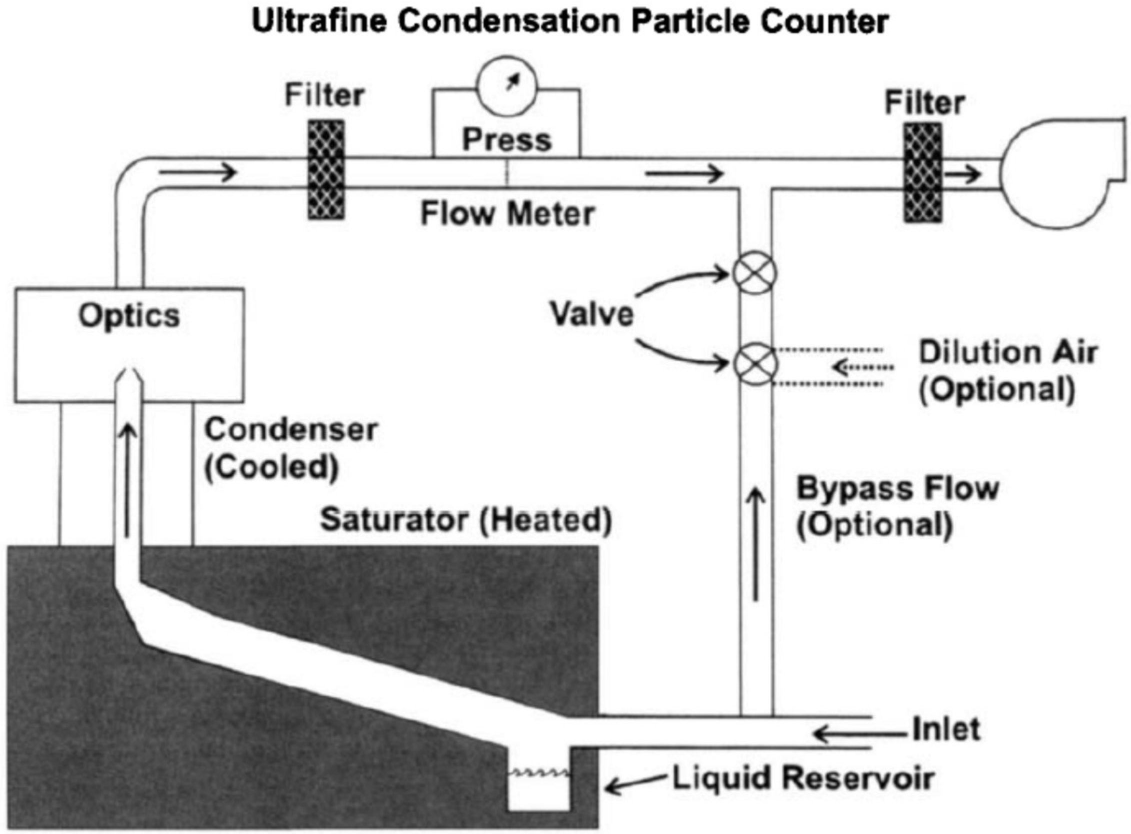
OPC (Optical Particle counters)



- Light Scattering
- Light Extinction

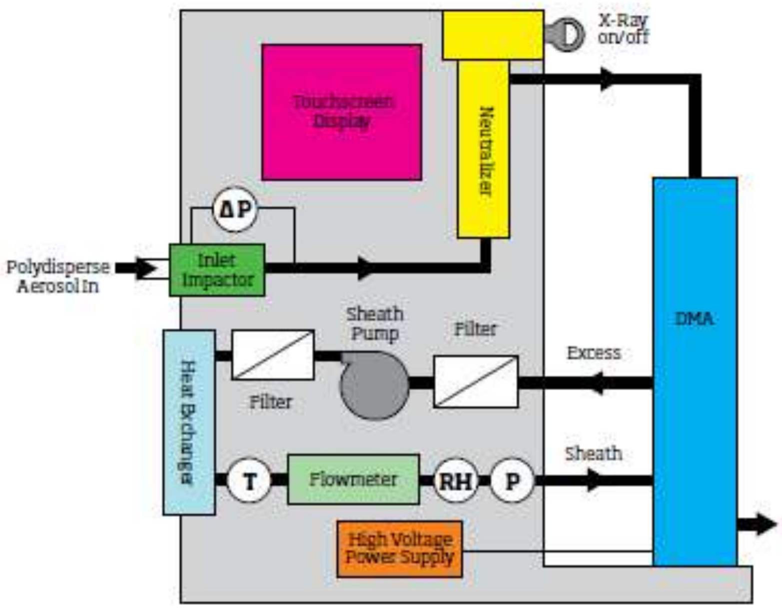
  $0.4 > l_{opt} > 0.7\ \mu m$
- Linear dependence of light scattering on particle mass concentration
- Scattering also depends on light absorbing nature of aerosols
- Single Particle /Cloud of Particles

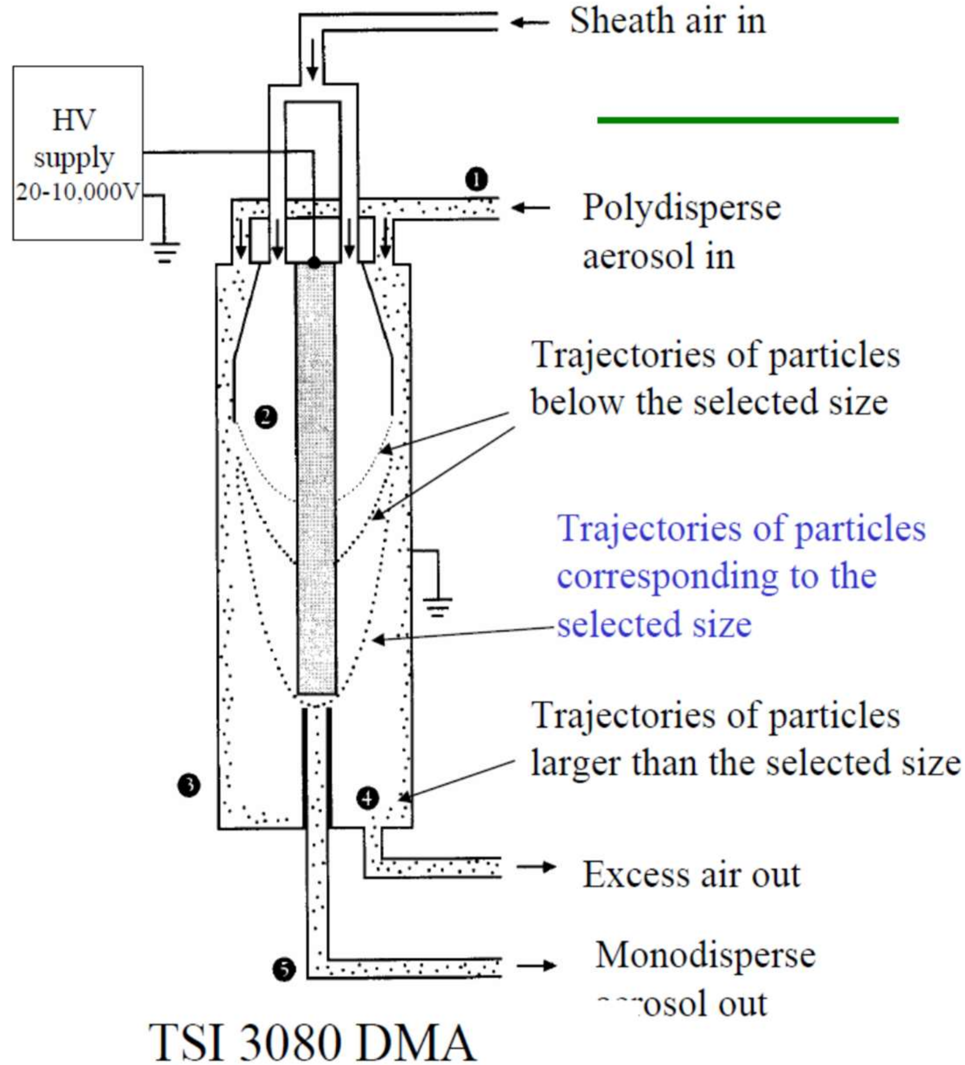
Ultrafine/Nanoparticle Particle Counting:
CPC (Condensation particle counter)



Willeke and Baron, 1999;
www.tsi.com

Ultrafine/Nanoparticle Particle sizing:
SMPS (Scanning mobility particle sizer)

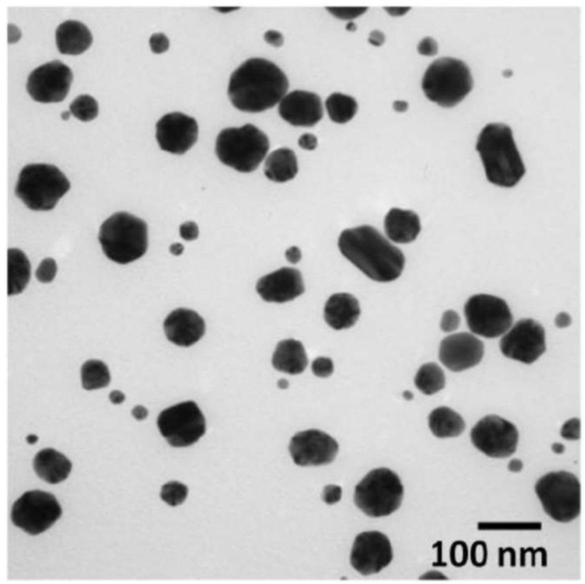


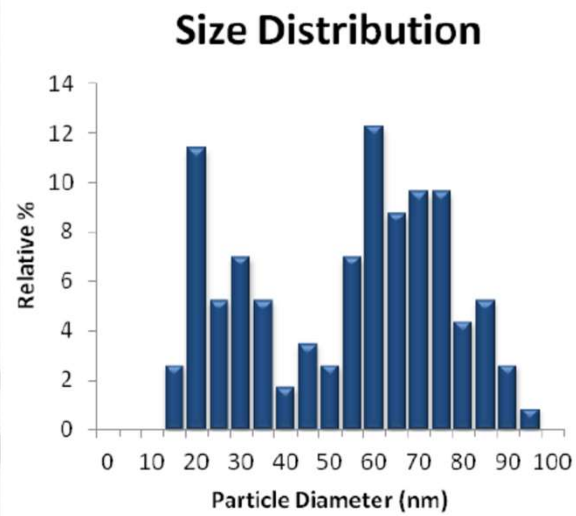


Willeke & Baron, 1999; www.tsi.com

Ultrafine/Nanoparticle Particle sizing:
Electron microscopy

TEM images are formed using transmitted electrons (instead of the visible light) which can produce magnification details up to 1,000,000x with resolution better than 10 A_o



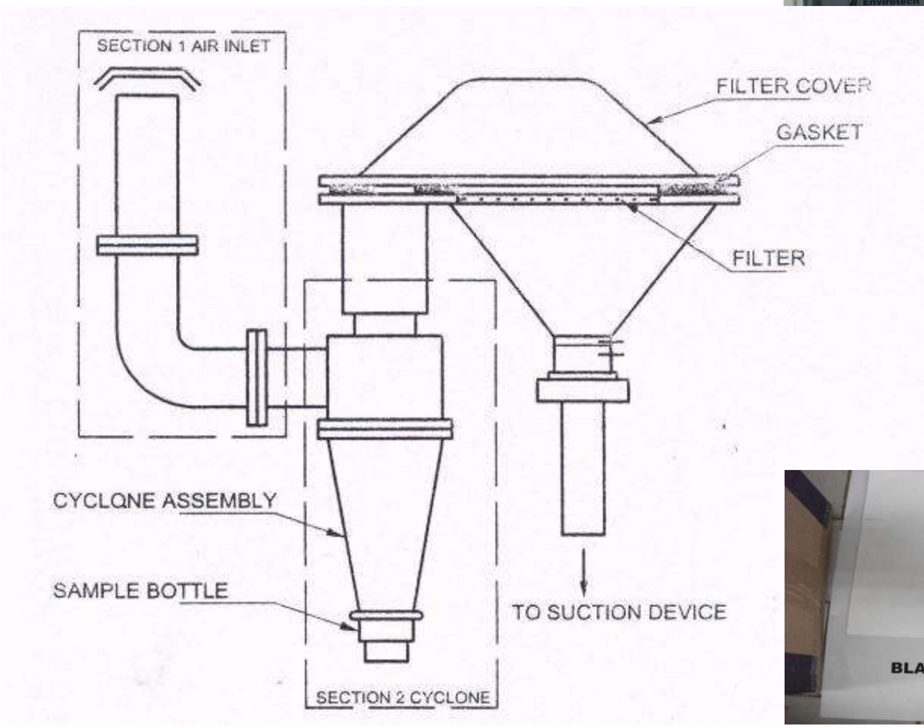


Willeke & Baron, 1999;
http://www.rsic.iitb.ac.in/tem.html

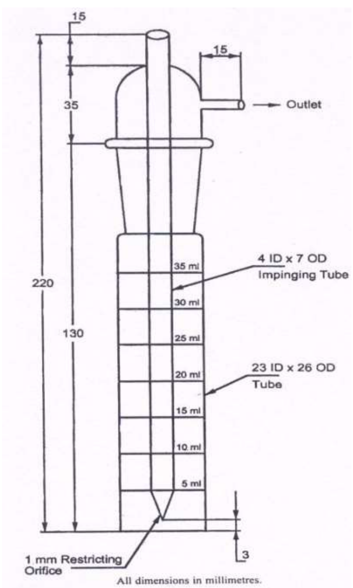
Other PM (& gas) Instruments

- High Volume (Hi-Vol) Samplers (1.2 Lakhs)
  - Gravimetric (Q =1 m^3/min; weight =60 kg)
  - Regulatory (PM_{10} or $PM_{2.5}$, SO_2, NO_2)

Cyclone inlet (PM_{10})



Impinger (NO_2, SO_2)



CPCB, 2011

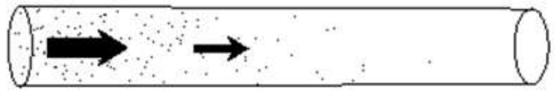
Other PM Instruments

- Mini Volume (Mini-Vol) Samplers (2 Lakhs)
  - Gravimetric (Q=5 L/min)
  - Regulatory (PM_{10}, $PM_{2.5}$)

- DustTrak (4 Lakhs)
  - Real time (1 minute resolution; Q=3 L/min)
  - PM_x (x = 1, 2.5, 4, 10)

Choice of instruments is a function of its cost, intended analysis, time resolution, portability, ease of use

Time-integrated (passive) methods - Gases



- Gases are collected in tubes/badges by diffusion
- Absorption substrate inside are coated with chemicals (e.g triethanolamine for NO_2)
- Post-collection analysed in wet-labs using colorometry

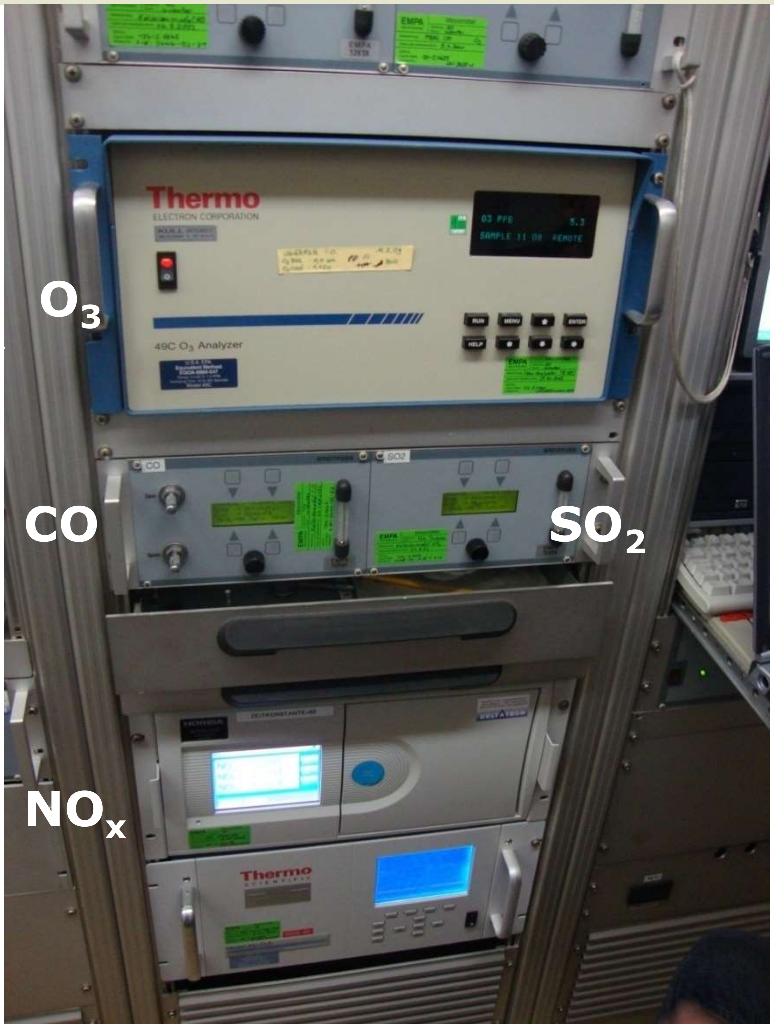
Ogawa NO_x

Passam NO_2/O_3

Ogawa deployed in field

Measurement methods - Gases

Passive samplers with electrochemical sensors; usually CO, CO_2, NO_x, O_3, HCHO, NH_3 etc. can be measured



Stacked reference gas monitors at AQM station; all gases are actively sampled and anlysed in real-time

Personal/Indoor Monitoring Methods







For personal and/or indoor monitoring, important criteria are:

- portability (instrument size),
- battery run-time, and
- noise it makes while running

Mixing/Dispersion

Meteorology

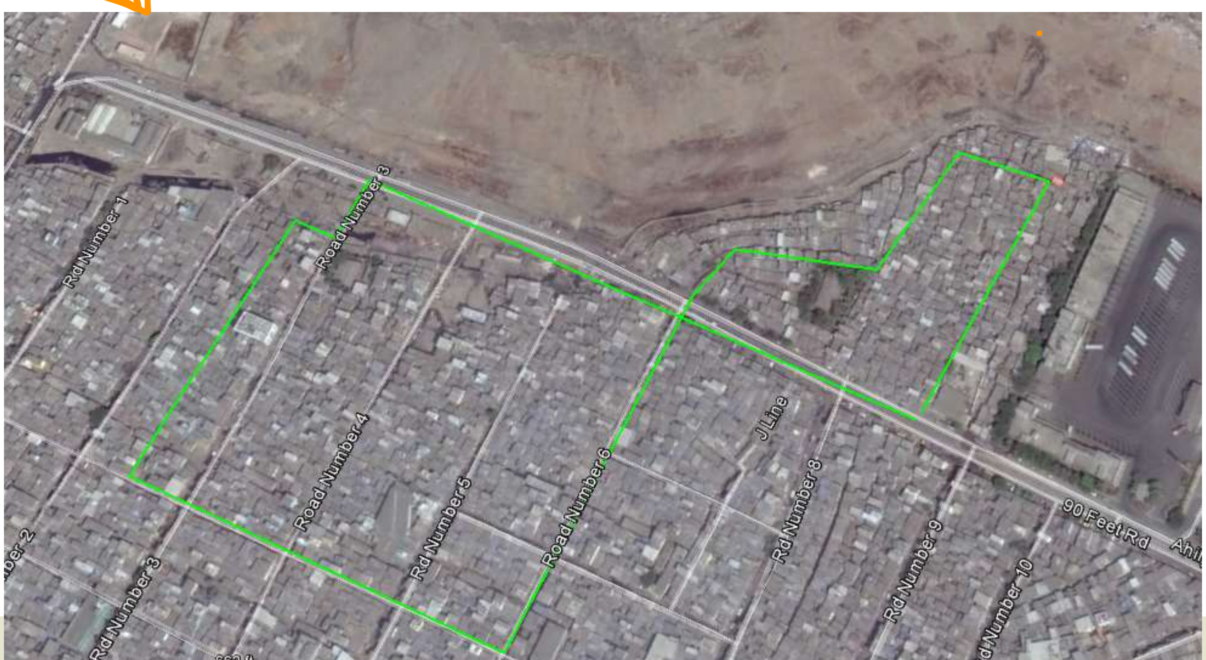
- Vertical
  - Temperature
    - Lapse Rate
- Horizontal
  - Wind
    - Speed
    - Direction

Other met. parameters

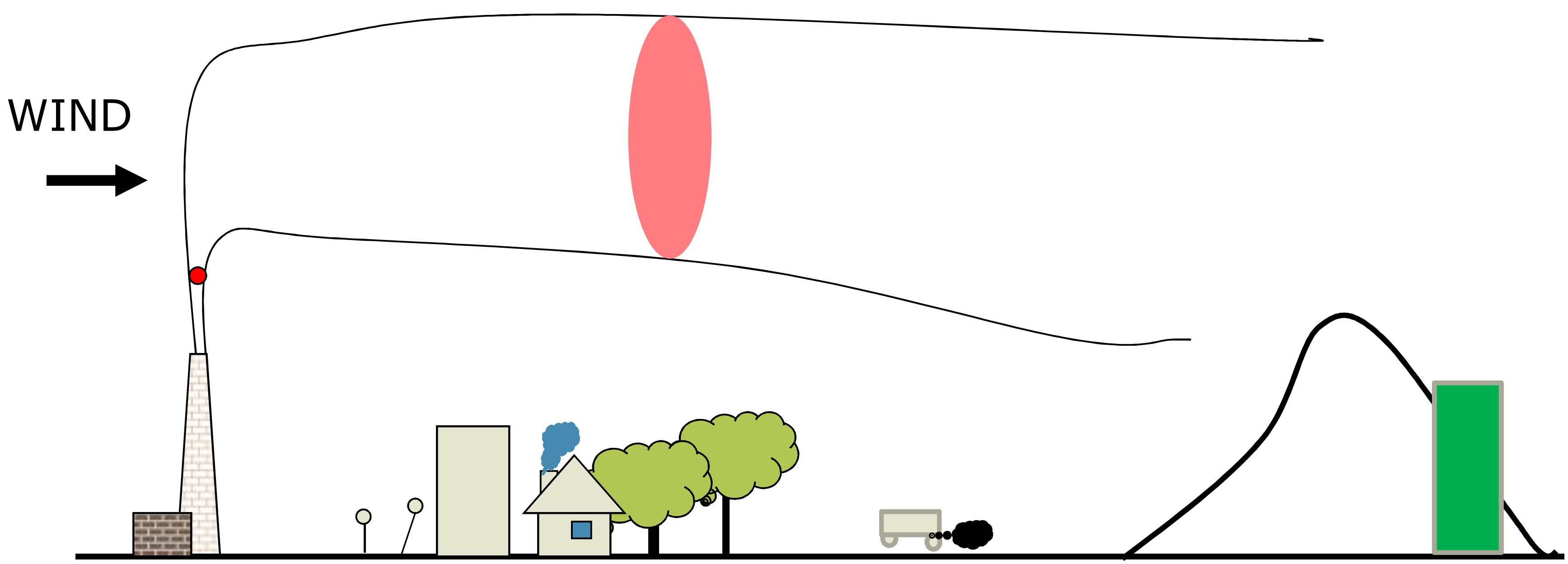
- Sunlight
- Precipitation
- Humidity

Types of Sources

- Point
- Line
- Area



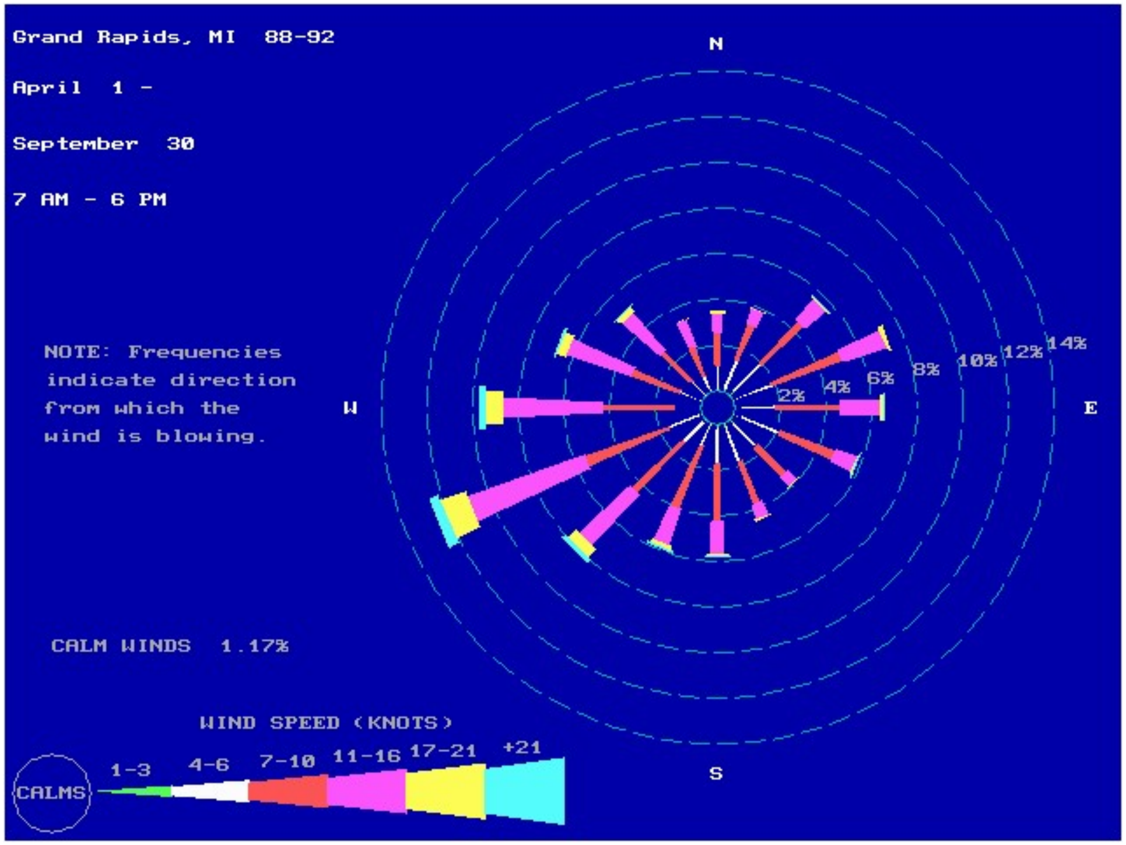
Dispersion – Gaussian Plume



Wind Rose

- Wind roses are divided into 16 wind directions
- Each wind direction is divided into wind speeds
- As the percent of time the wind blows from a particular directions gets larger, the portion of the bar representing the wind speed gets larger both in length and width

1 knot = 1.82 km/hr



http://www.epa.gov/ttn/naaqs/ozone/areas/wind.htm#dlfi

Wind Rose

Have you heard of the following?

- ‘easterly winds’ (*purvai*)
- ‘westerly winds’ (*pachhua*)

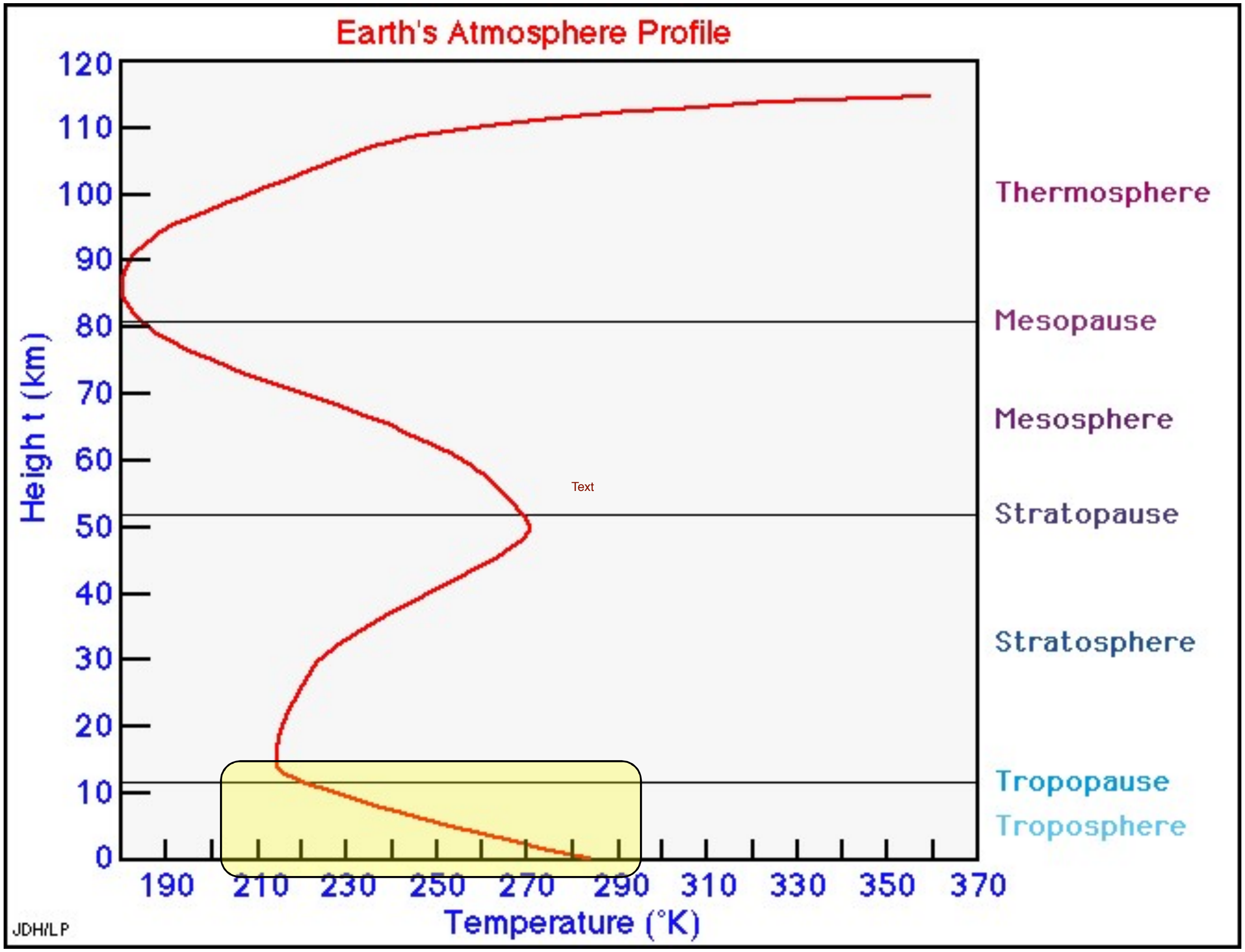
Pachhua is cold in winters and warm in summer. *Purvai*, on the other hand, has pleasant temperature. During pre-monsoon /monsoon, however, *Purvai* carries humidity, making the weather unbearable under the hot Sun.

Mixing/Dispersion

Meteorology

- Vertical
  - Temperature
    - Lapse Rate
- Horizontal
  - Wind
    - Speed
    - Direction

Atmospheric Temperature profile



Text

http://www.ldeo.columbia.edu/edu/dees/ees/climate/slides/atmprofile.gif

Lapse Rates

Atmosphere cools with height

@what rate ?

- Dry (Adiabatic) 10°C/km
- Wet (Adiabatic) 6°C/km
  (Release of heat with condensation)

$$\Gamma = -\frac{dT}{dz} = -\frac{g}{C_P} = -1\,°\mathrm{C}/100\ \mathrm{m}$$

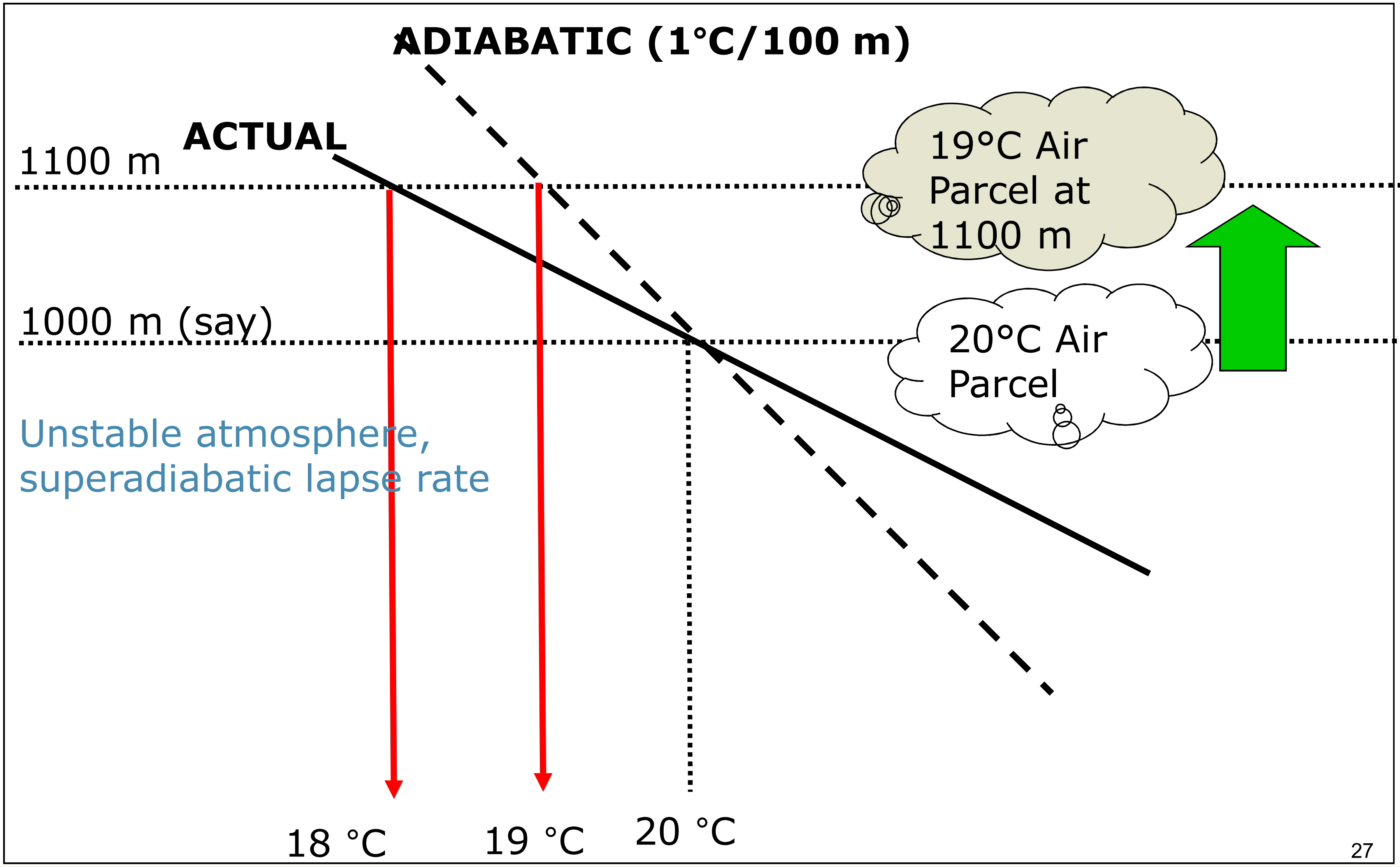
Actual lapse rate

$< \Gamma$, unstable or super-adiabatic

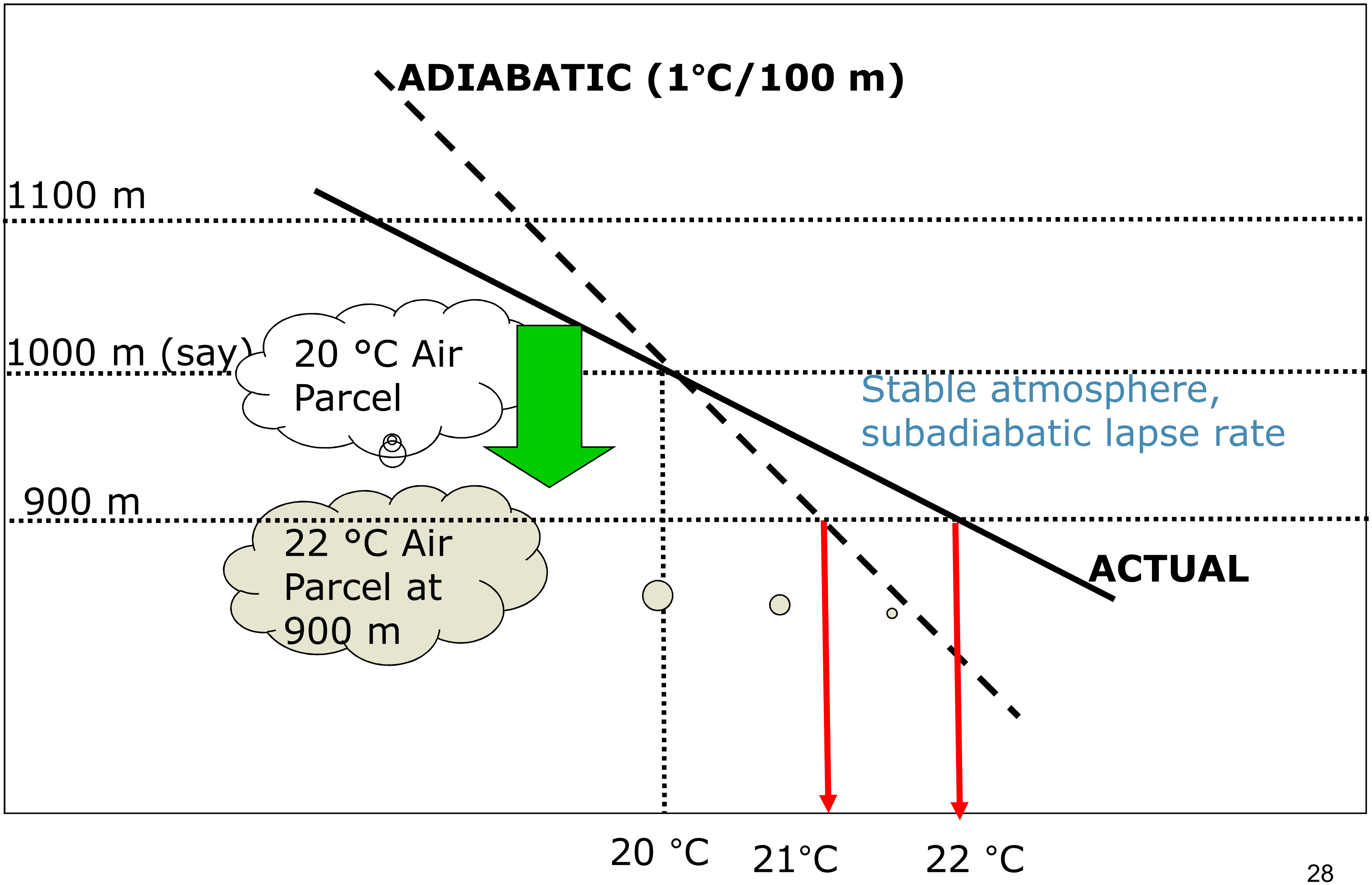
$> \Gamma$, stable or sub-adiabatic

$= \Gamma$, neutral (same rate)

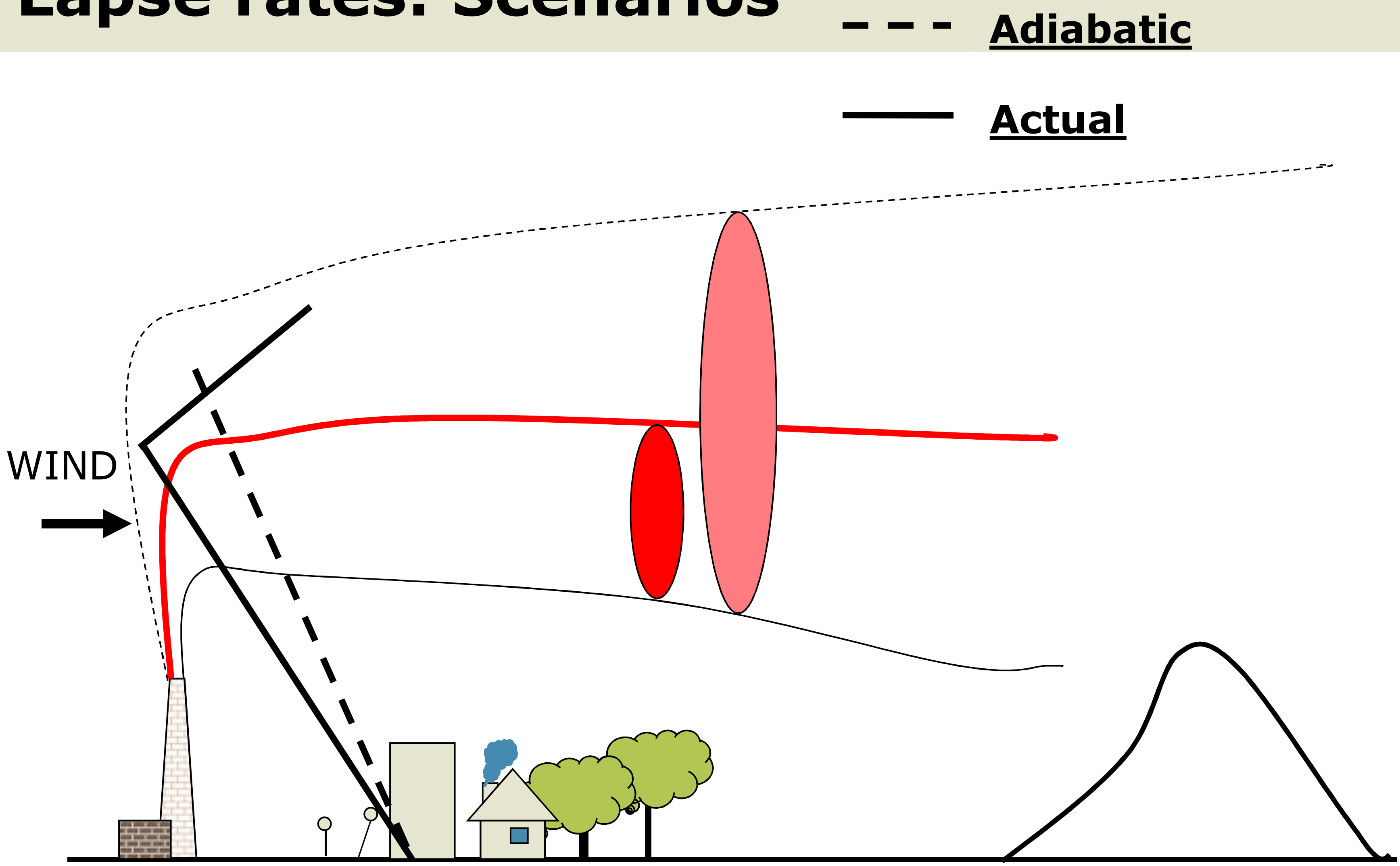
Vertical mixing: Lapse Rates



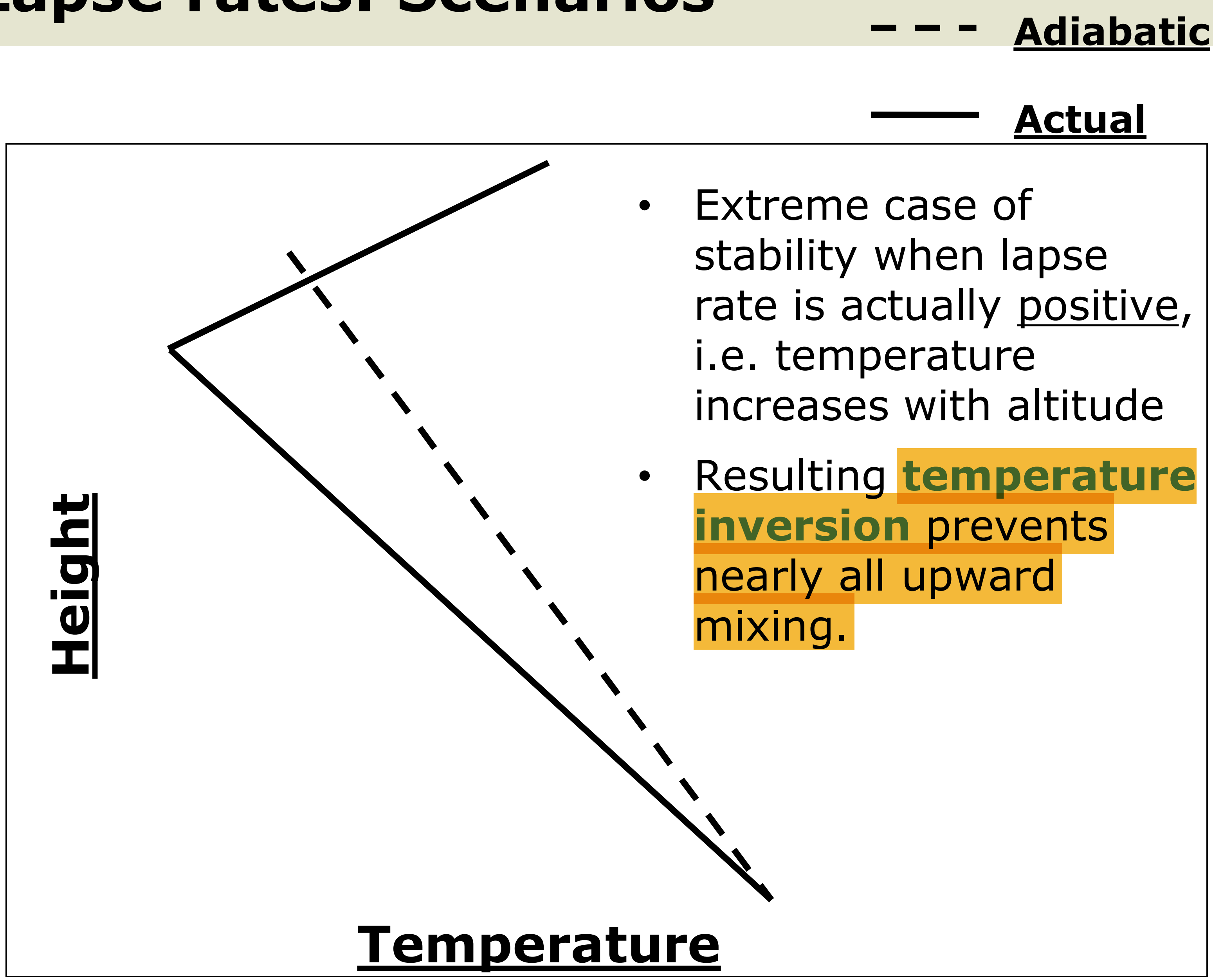
Vertical mixing : Lapse Rates



Lapse rates: Scenarios

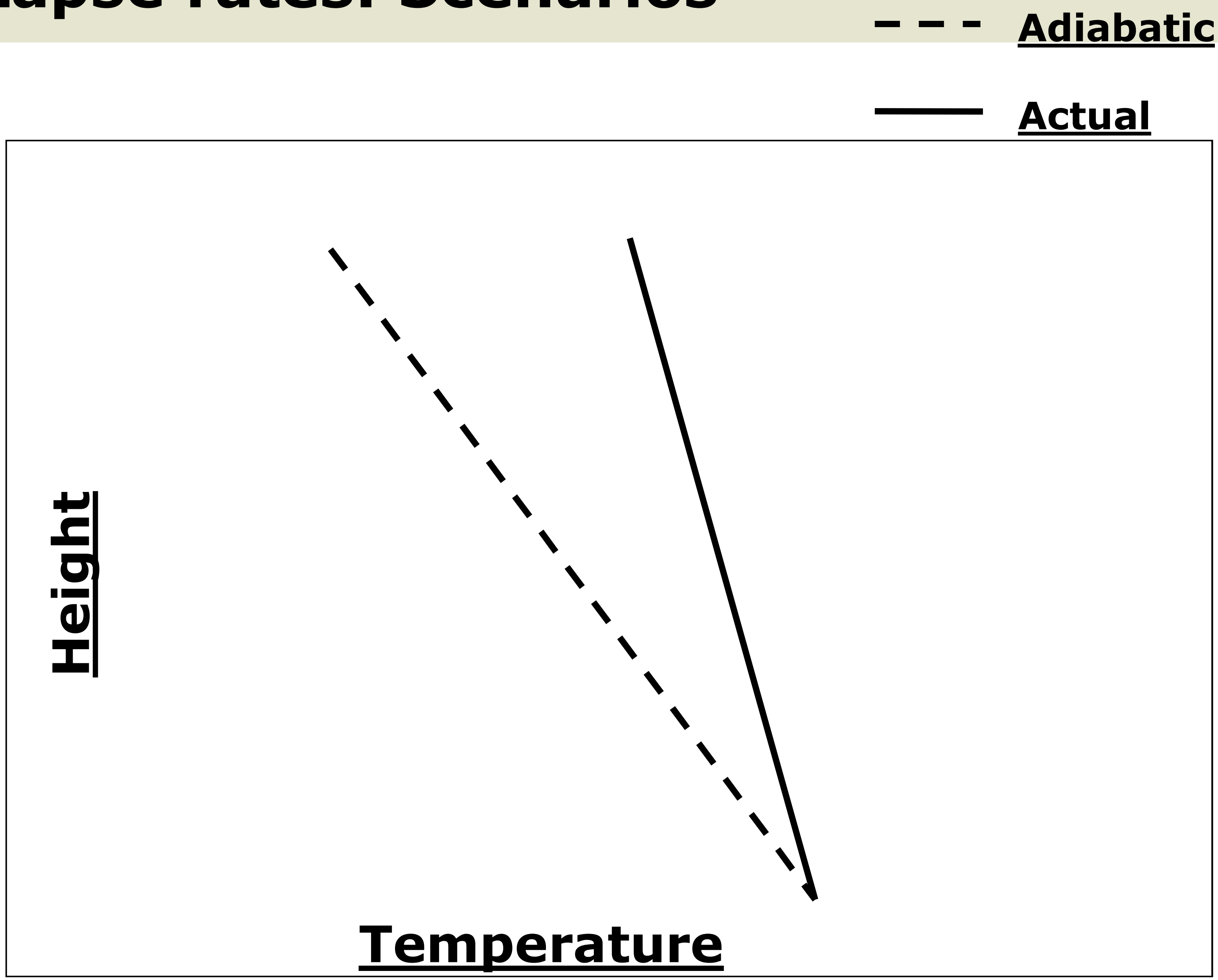


Lapse rates: Scenarios

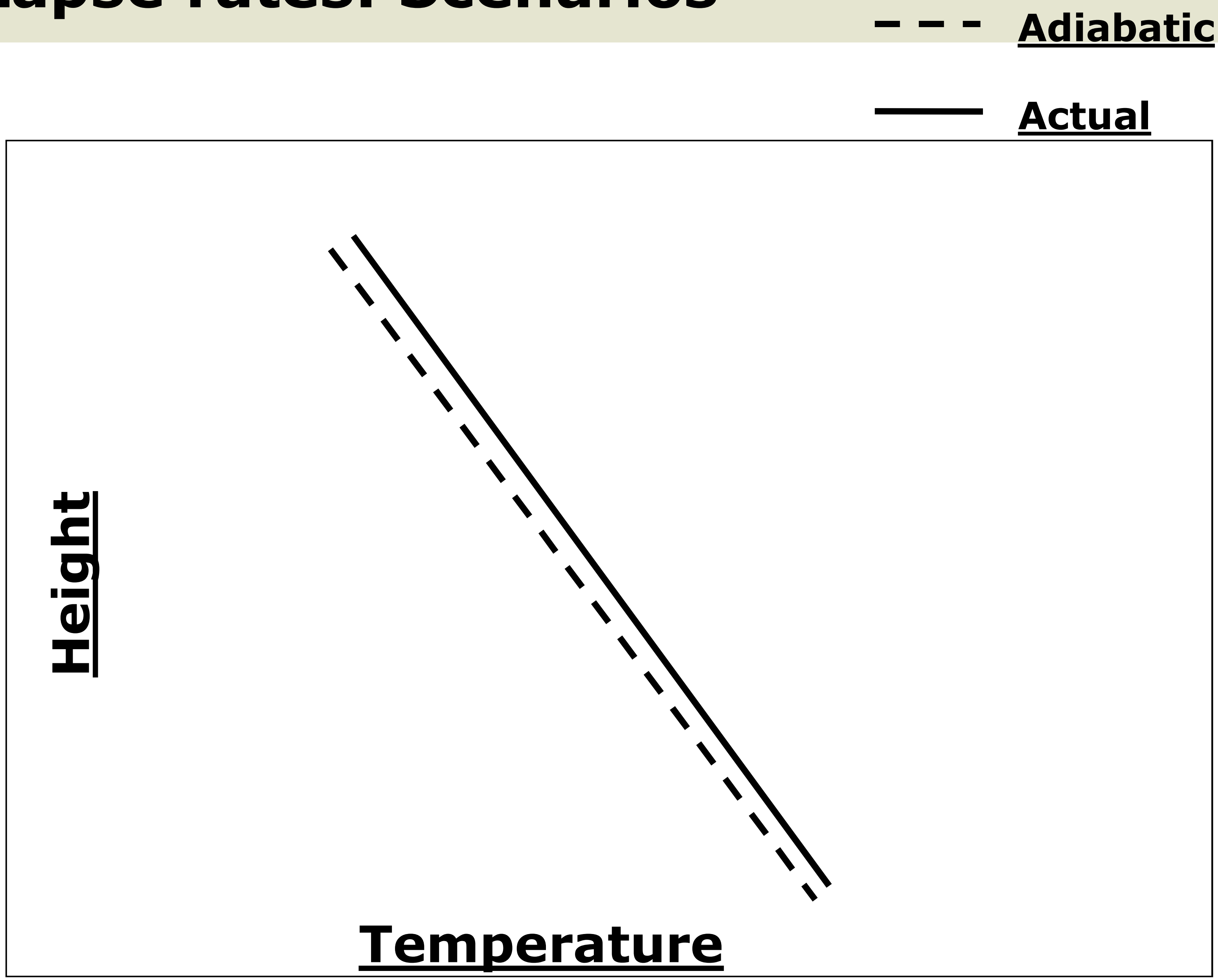


- Extreme case of stability when lapse rate is actually <u>positive</u>, i.e. temperature increases with altitude
- Resulting **temperature inversion** prevents nearly all upward mixing.

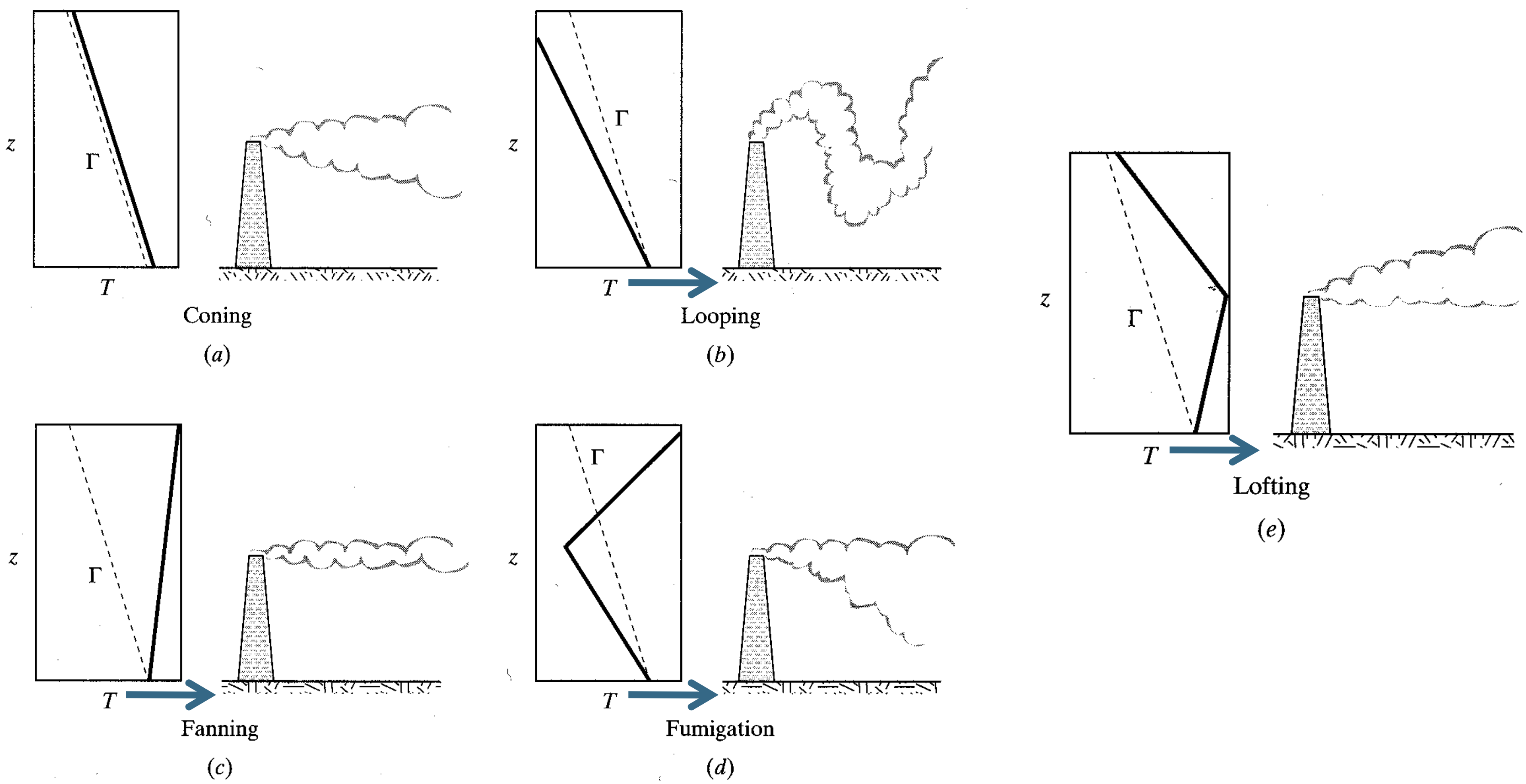
Lapse rates: Scenarios



Lapse rates: Scenarios

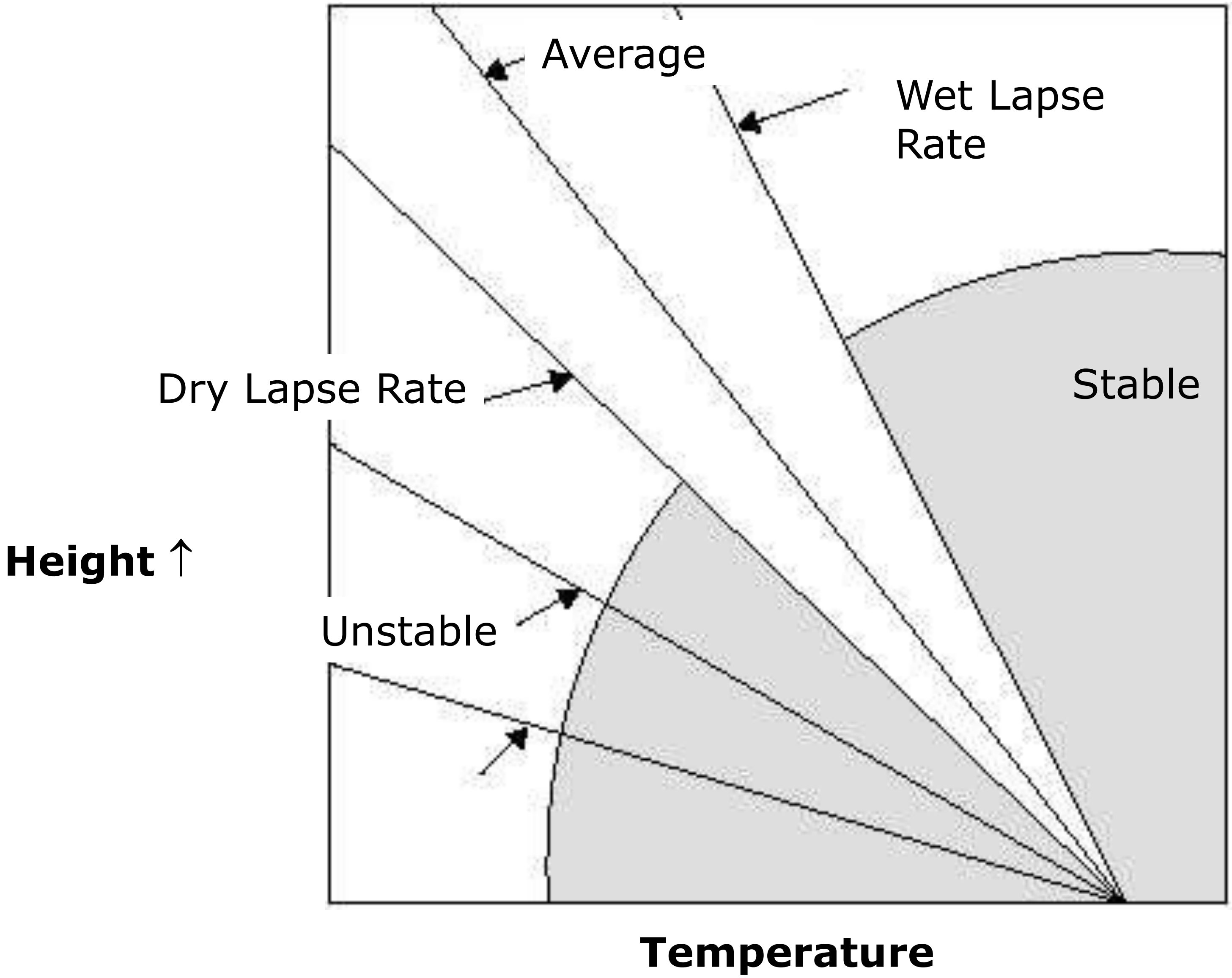


Effect of Lapse Rate on Plumes



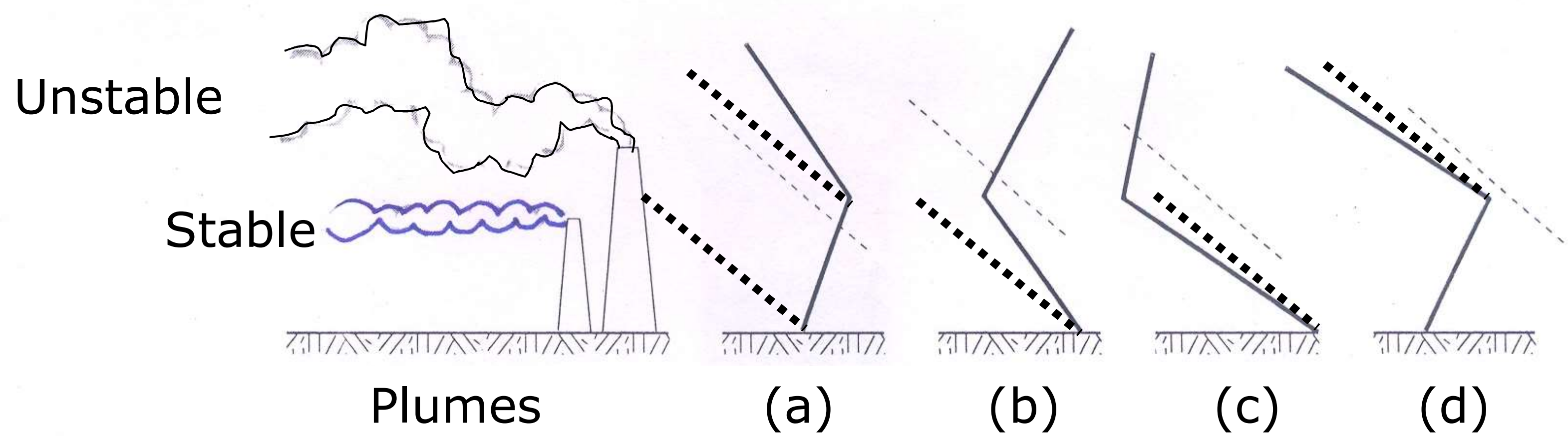
Masters & Ela, 2008

Atmospheric Stability



http://www.tpub.com/content/aerographer/14312/css/14312_47.htm

Class Problem: Match the Profile !



(Adapted from Masters, 1997)

Next class on:

Thu, 17.Aug, 10:35am