# Atmospheric Aerosols :
# physical properties; chemical composition; health & environmental effects

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# Atmospheric Aerosols

1. Introduction
2. Sources
3. Classification
4. Chemical Composition
5. Health effects
6. Environmental effects

# Introduction

- Suspensions of **liquid** or **solid** particles in gas (called an aerosol)

1. Liquids – mist, fog
2. Solids – smoke, fumes, fly ash, dust
3. Smog = Smoke + fog

Diameter range **1nm** to **100μm**

# Typical atmospheric aerosols

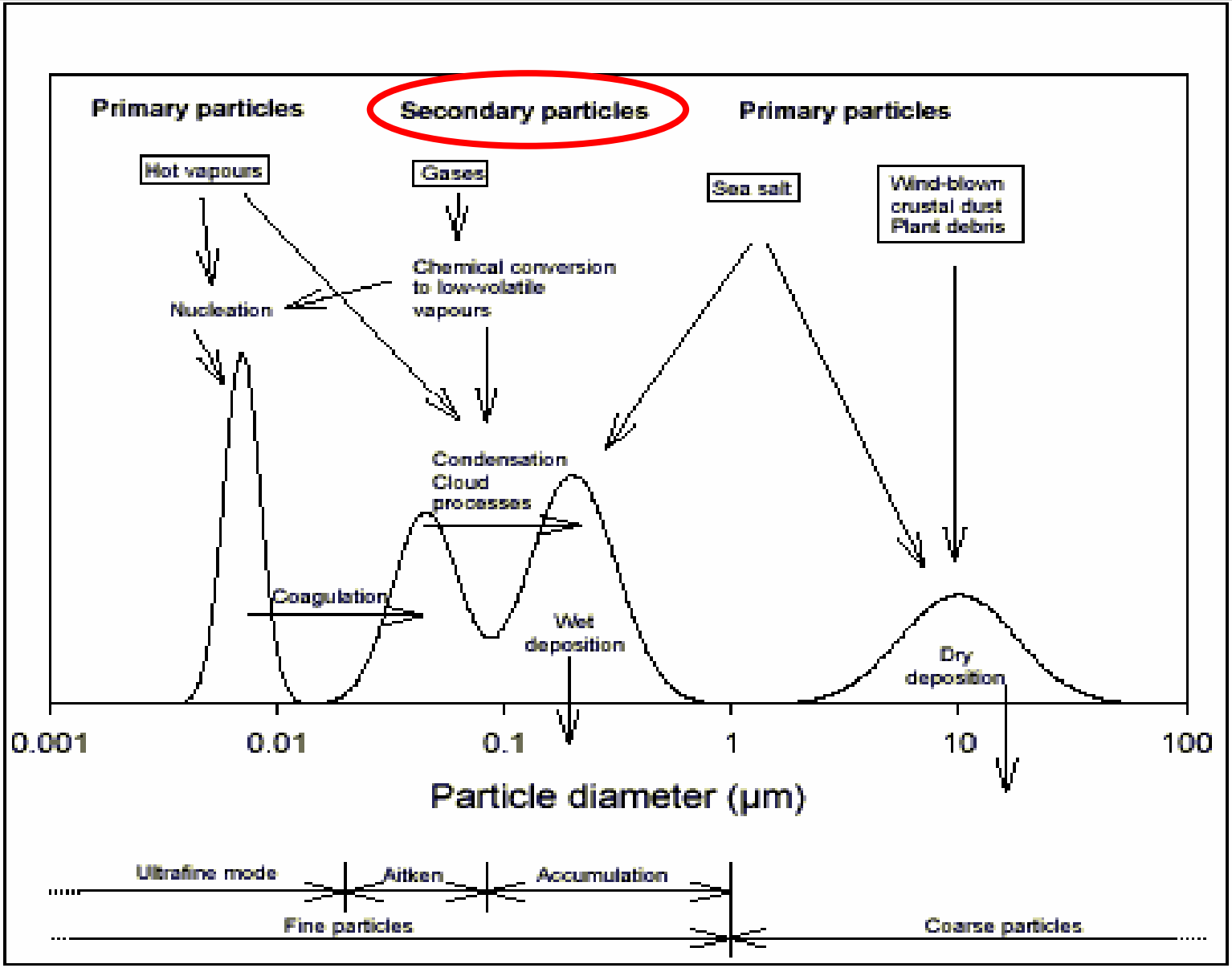
Forest fires


Soil erosion


Volcano eruptions

Industrial activities

# Size distribution

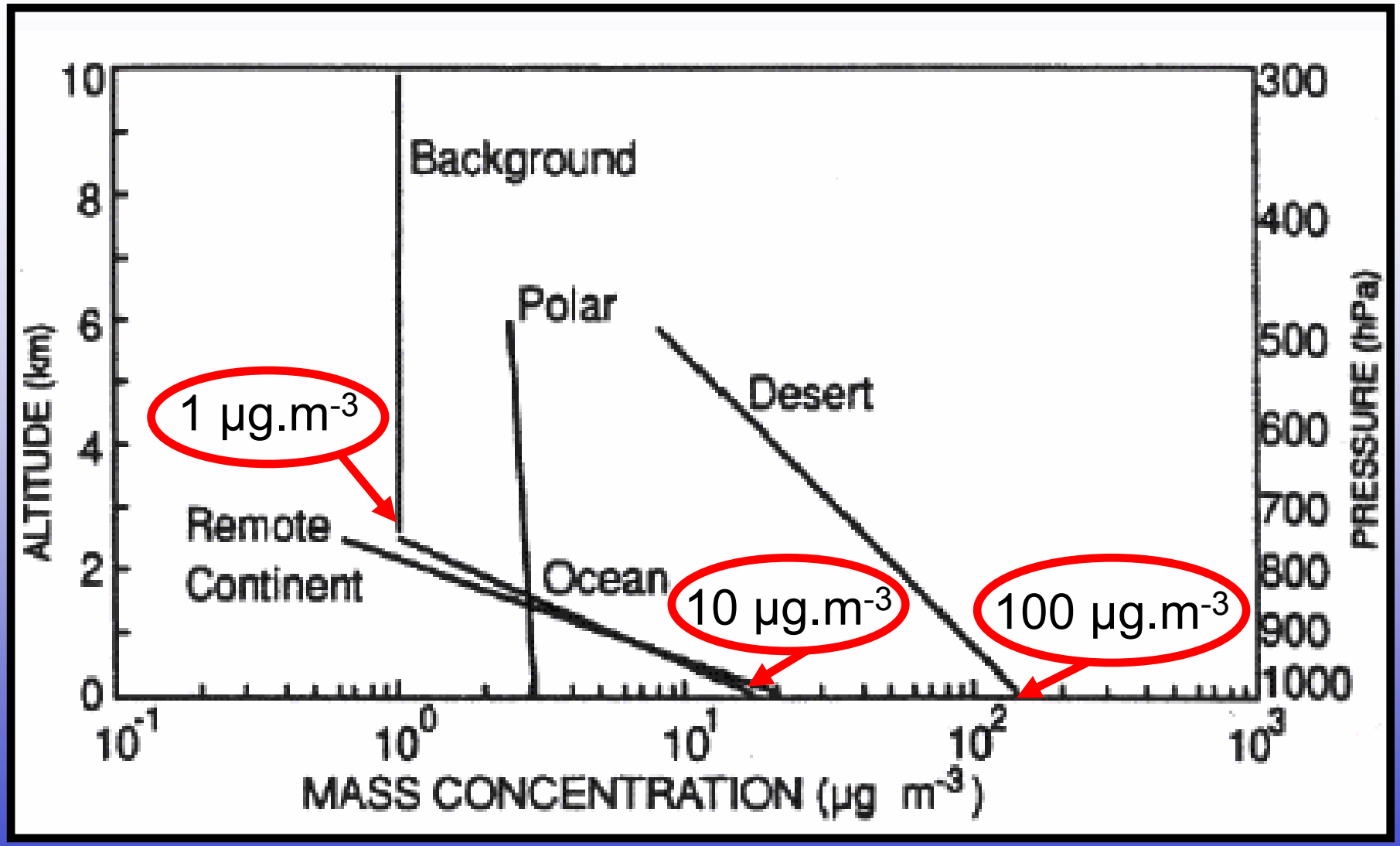



*Idealised and simplified schematic illustration of atmospheric aerosols, including sources, transformation and sinks. The different size ranges (modes) are also shown.*

# Global emissions of major atmospheric aerosols

| | EMISSION | TYPICAL SIZE | TYPICAL COMPOSITION |
|---|---|---|---|
| **NATURAL** | | | |
| **PRIMARY** | | | |
| SOIL DUST | 1500 | > 1 µm | Si, Al, Fe, Ca… |
| SEA SALTS | 1300 | > 1 µm | Na, Cl, S |
| VOLCANIC DUSTS | 30 | > 1 µm | Si, Al, Fe |
| BIOLOGICAL DEBRIS | 50 | > 1 µm | C |
| **SECONDARY** | | | |
| SULFATES FROM BIOGENIC GASES | 130 | < 1 µm | S |
| SULFATES FROM VOLCANIC $SO_2$ | 20 | < 1 µm | S |
| ORGANIC MATTER FROM BIOGENIC VOC | 60 | < 1 µm | C |
| NITRATES | 30 | > 1 µm | Na |
| **TOTAL NATURAL** | **3100** | | |
| **TOTAL NATURAL < 1 µm** | **210** | | |
| **MAN-MADE** | | | |
| **PRIMARY** | | | |
| INDUSTRIAL PARTICULATES | 100 | > 1 µm | C, Si, Al, Fe, heavy metals |
| DUSTS | 600 | > 1 µm | C, N, Si, Al, Fe, Ca… |
| SOOT | 10 | < 1 µm | C |
| BIOMASS BURNING | 90 | | |
| **SECONDARY** | | < 1 µm | S |
| SULFATES FROM $SO_2$ | 190 | < 1 µm | C, K, metals |
| NITRATES FROM NOx | 50 | < 1 µm | N |
| ORGANICS FROM MAN-MADE VOC | 10 | < 1 µm | C, N |
| **TOTAL MAN-MADE** | **1050** | | |
| **TOTAL MAN-MADE < 1 µm** | **350** | | |
| **TOTAL** | **4150** | | |

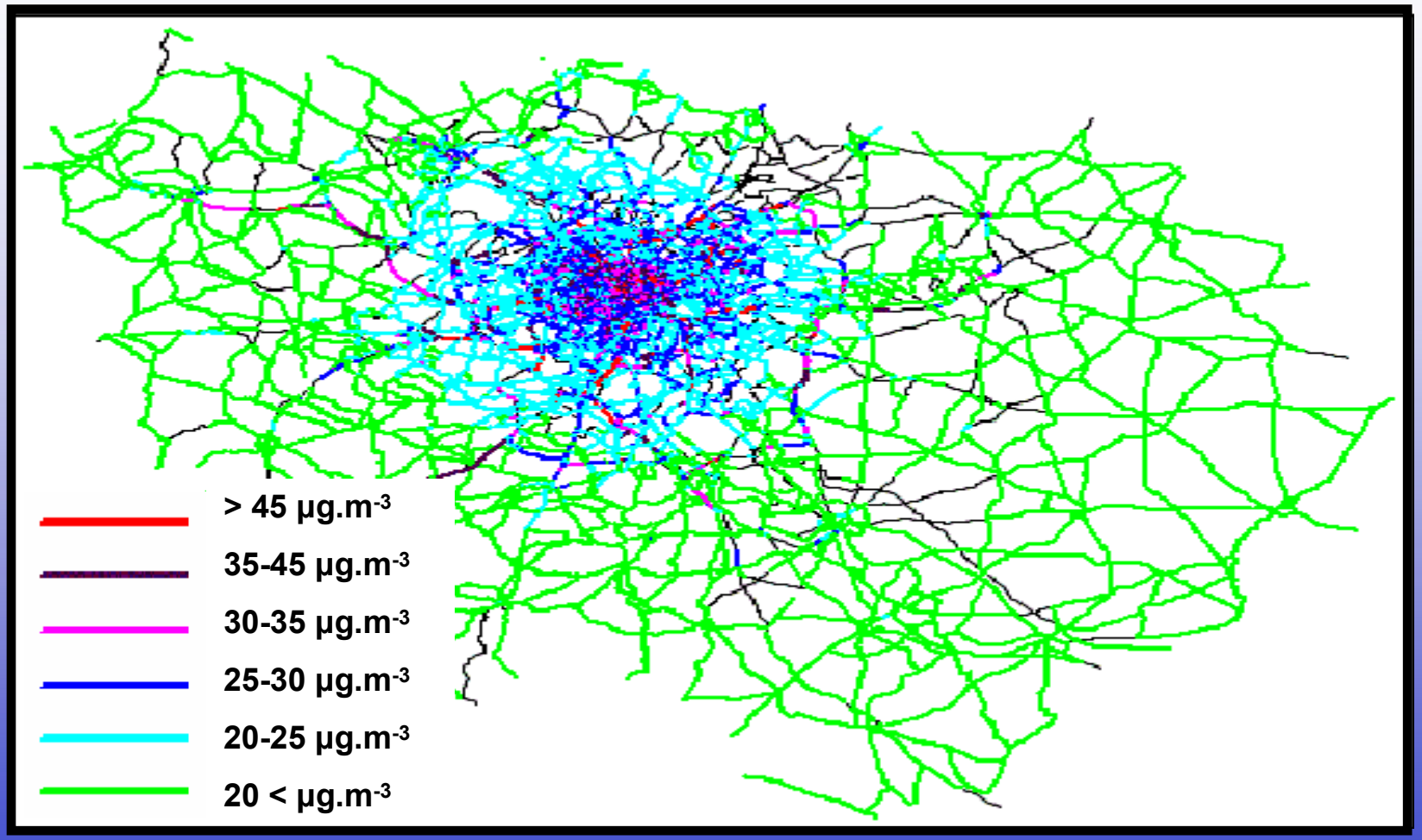
# Atmospheric aerosol concentration ranges




Wide spatial concentration disparities in the troposphere (both horizontally and vertically)

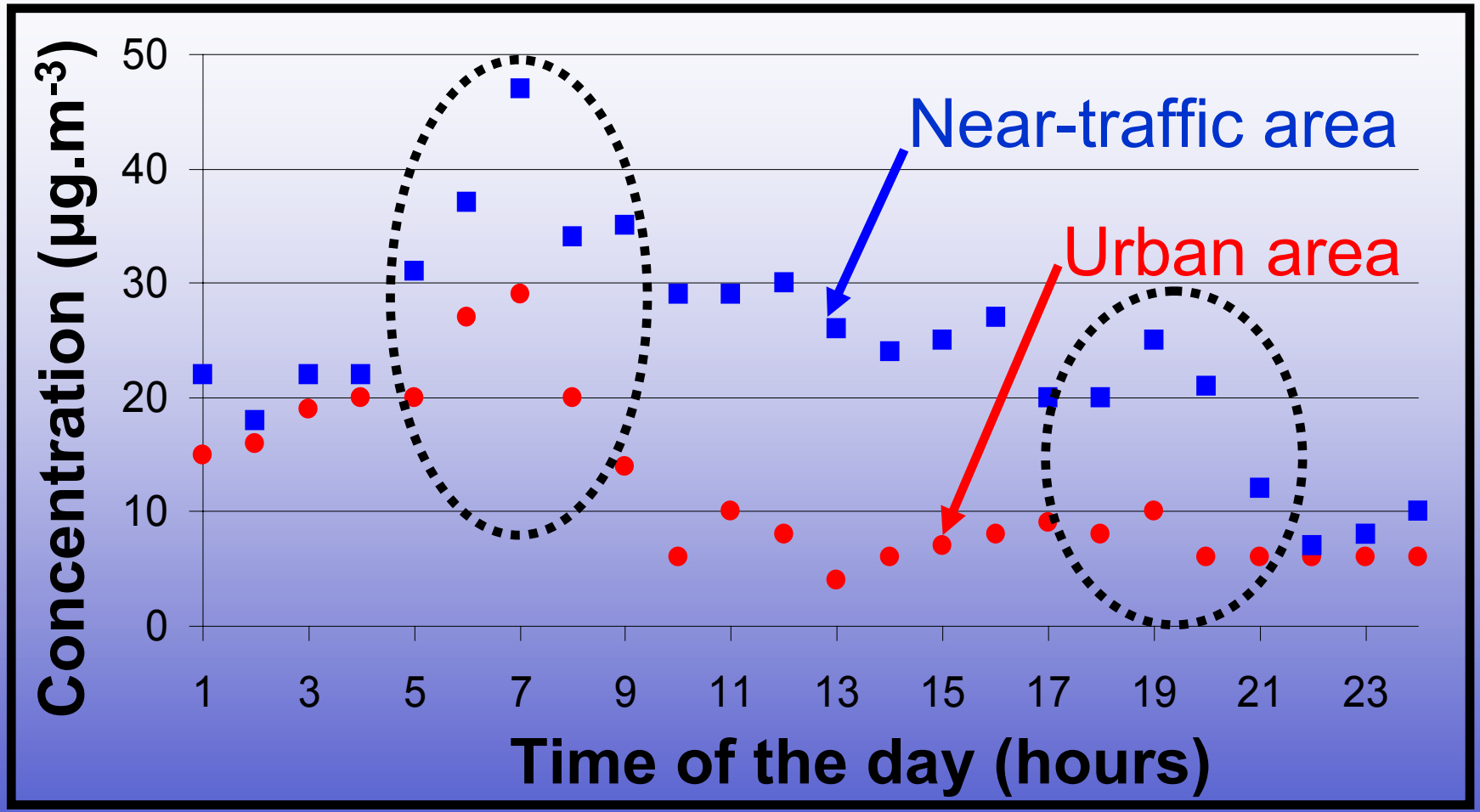
# Atmospheric aerosol concentration ranges

## Concentration gradient of particles within a city (Paris)




Wide spatial concentration disparities within a urban area

# Atmospheric aerosol concentration ranges




Wide temporal concentration (hourly example)

# Atmospheric aerosol concentration ranges

Wide spatial and temporal concentration disparities

Spatial :

- Desert ≥ Urban areas > Ocean surface > Pole
- Remote > Rural > Urban

Temporal :

- *Hourly* : Traffic hours (morning and evening) > Night-time
- *Daily* : Monday-Friday > Saturday and Sunday
- *Seasonal* : Winter > Summer (heating systems)

**OR** Summer > Winter if photochemical activity is important (production of Secondary organic aerosols)

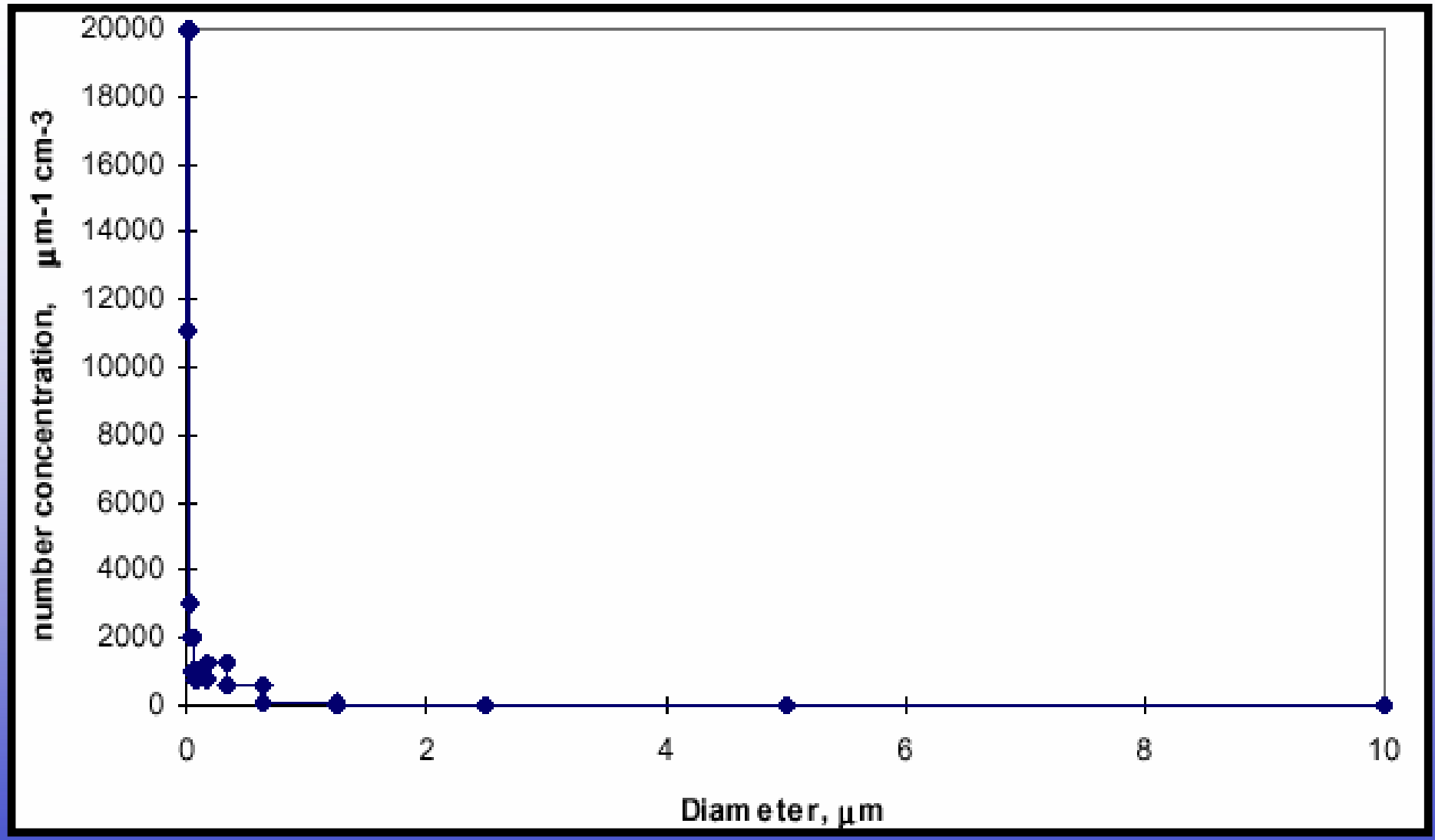
# Atmospheric size distribution

| Size range $\Delta D_p$ (μm) | Concentration $N_p$ ($cm^{-3}$) | Normalized Concentration $N_{norm}$ ($\mu m^{-1}.cm^{-3}$) |
|---|---|---|
| 0.001 – 0.01 | 100 | 11111 |
| 0.01-0.02 | 200 | 20000 |
| 0.02-0.03 | 30 | 3000 |
| 0.03-0.04 | 20 | 2000 |
| 0.04-0.08 | 40 | 1000 |
| 0.08-0.16 | 60 | 750 |
| 0.16-0.32 | 200 | 1250 |
| 0.32-0.64 | 180 | 563 |
| 0.64-1.25 | 60 | 98 |
| 1.25-2.5 | 20 | 16 |
| 2.5-5.0 | 5 | 2 |
| 5.0-10.0 | 1 | 0.2 |

**If the size range has $N_p$ particle concentration, the normalized concentration is**

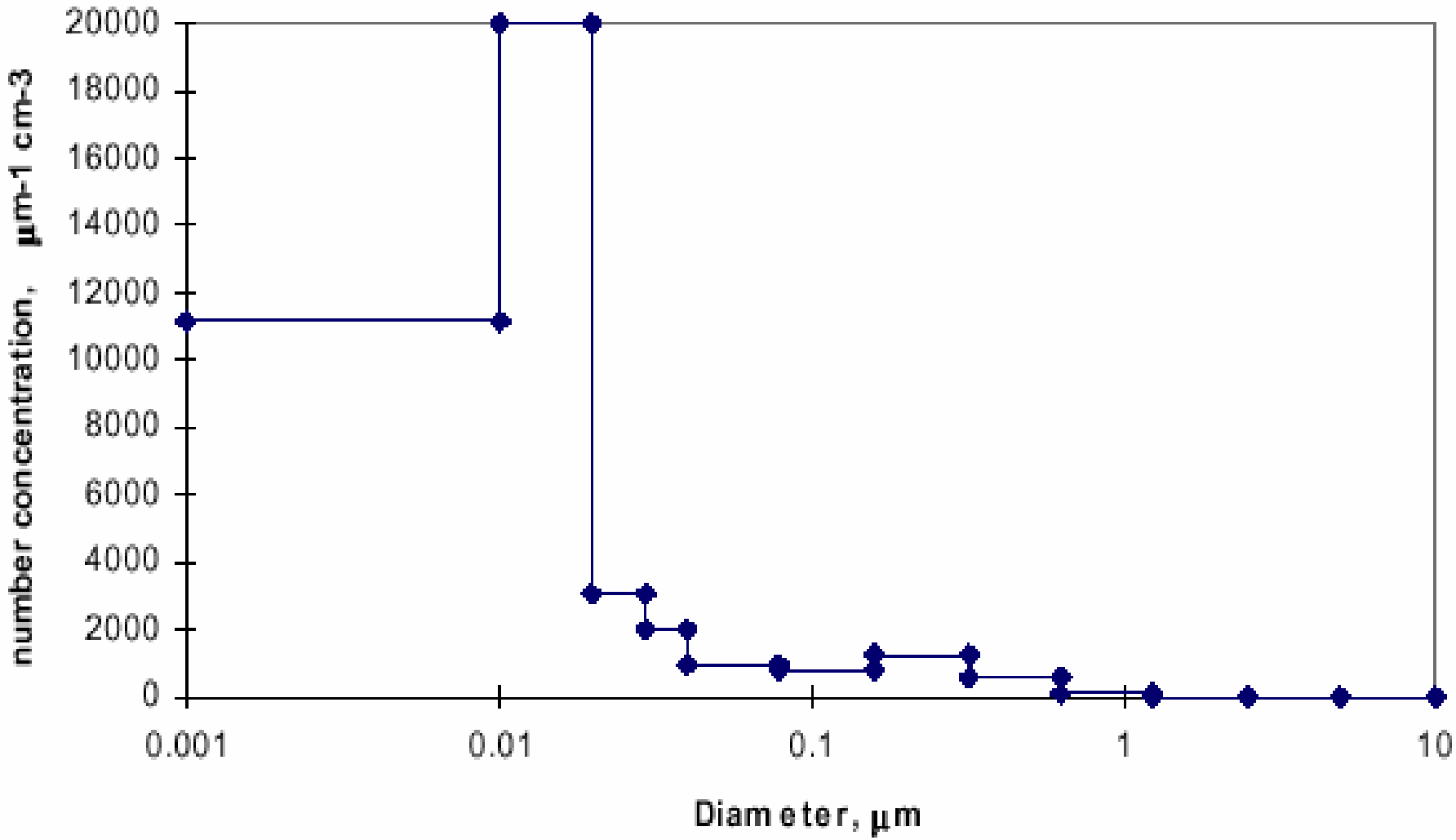
$$N_{normalized} = N_p/\Delta D_p$$

# Atmospheric size distribution



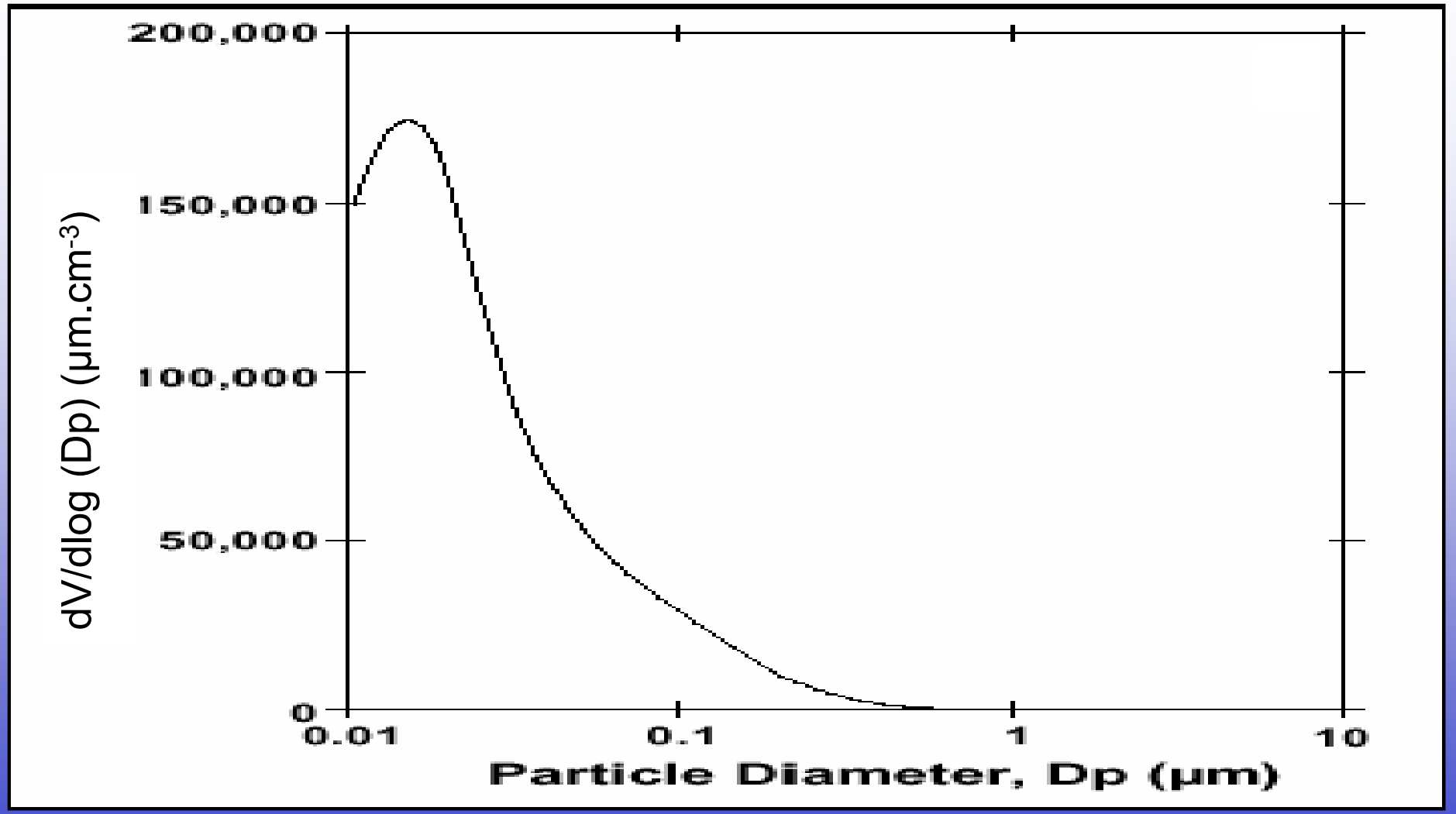

**Wide size range leads to lost information for smallest particle sizes**

# Atmospheric size distribution



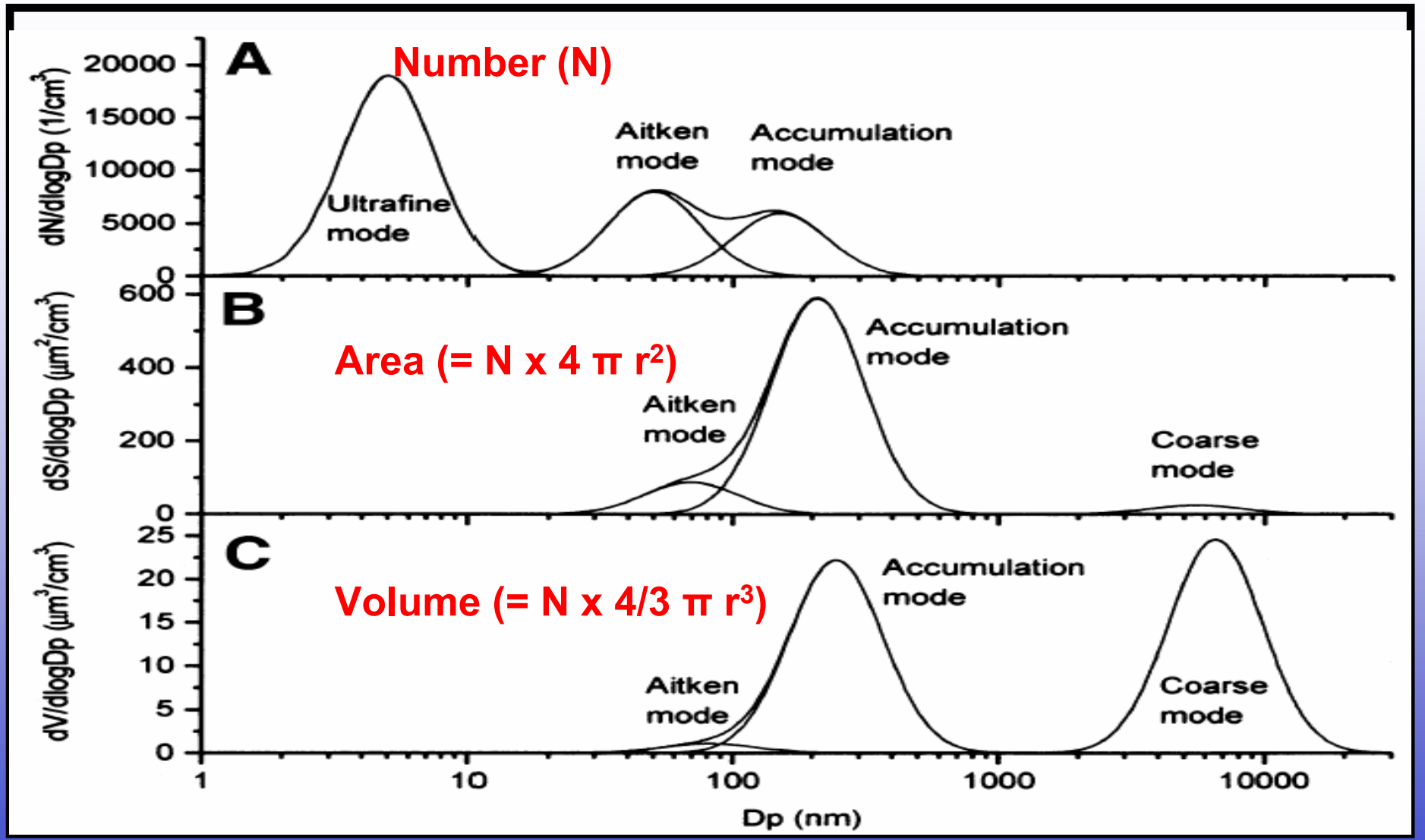

**With a log scale for the diameter, both small and large particles size ranges are depicted**

# Atmospheric size distribution




**The area under the curve is proportional to the concentration**

# Size distribution in number, area and volume



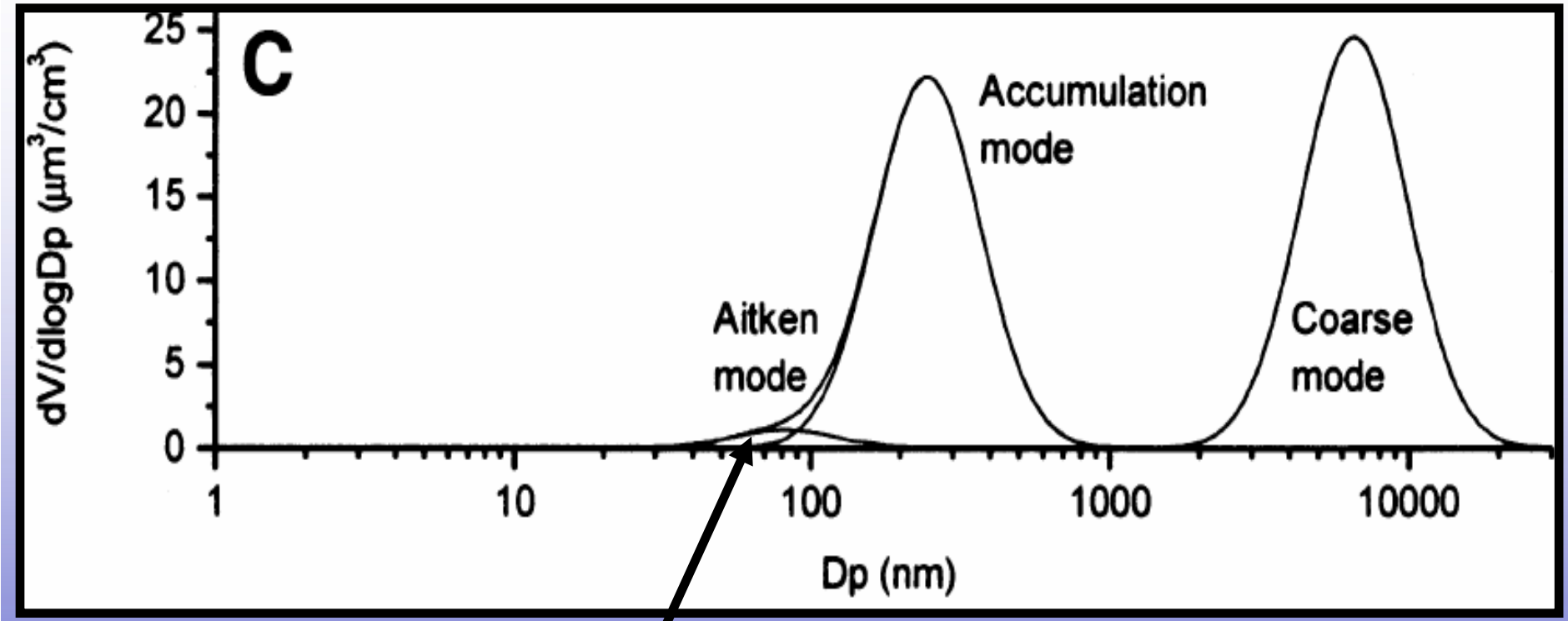

**Distribution varies with the parameter considered**

# Size distribution in number, area and volume

**Parameter to be considered varies with the studied processes :**

- **Surface area : Gas-phase interactions such as Partitioning, heterogeneous reactivity, health Effects**
- **Number : Cloud formation, Health effects**
- **Volume/Mass : Environmental fluxes, health effects (mass = volume x density)**

# Classification of atmospheric aerosols




**1. The nucleation (or Aitken) mode : Ø < 0.1 μm**
**Originate from the gas phase condensation. Mainly man-made sources, such as combustion activities and SOA formation; they rapidly coagulate**

# Processes involved in aerosol formation for the nucleation mode

- **Nucleation:** condensation of low-vapour-pressure gaseous species. Homogeneous nucleation

$$H_2O_{(g)} + H_2O_{(g)} \longrightarrow 2H_2O_{(l)}$$

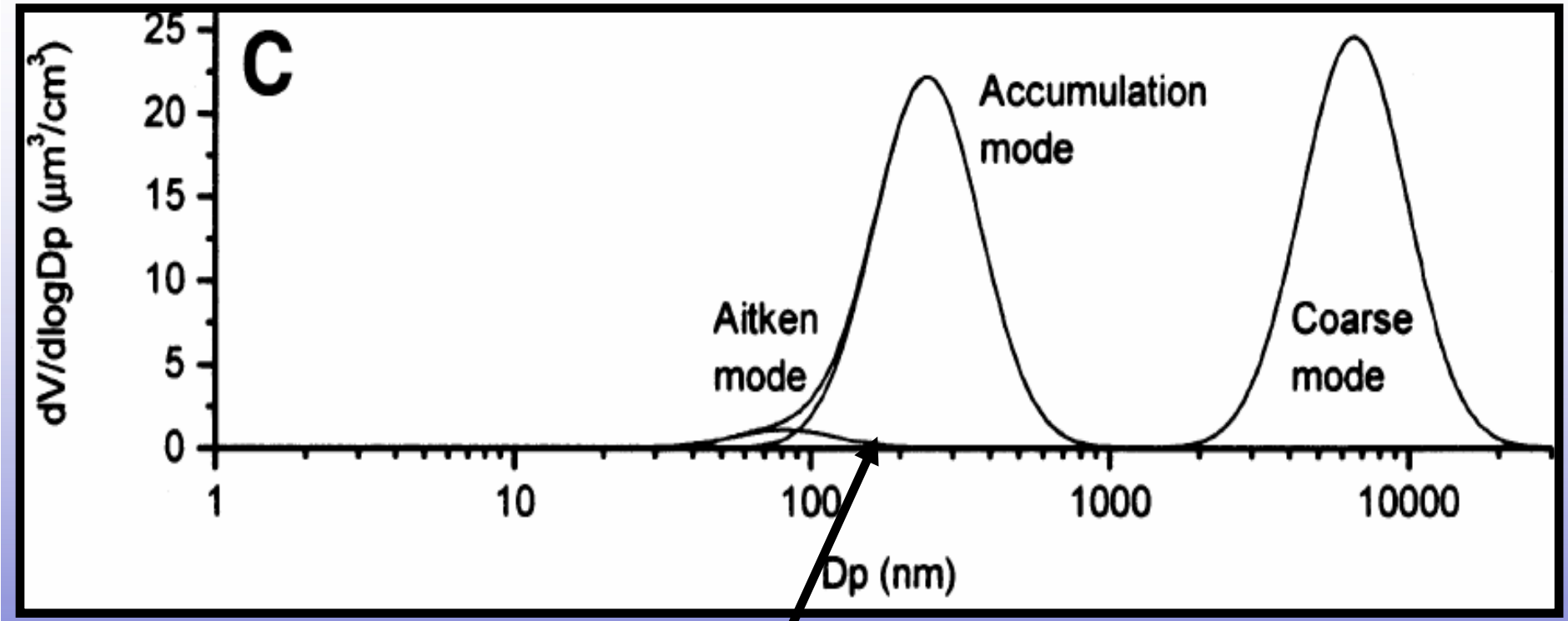
- **Condensation:** of a gaseous species on pre-existing particles. Heterogeneous nucleation or scavenging

$$NaCl_{(s)} + H_2O_{(g)} \longrightarrow NaCl_{(aq)}$$

- **Coagulation:** formation of particles through collision and sticking smaller particles together

$$NaCl_{(s)} + NaCl_{(s)} \longrightarrow 2NaCl_{(s)}$$

# Classification of atmospheric aerosols




**2. The accumulation mode : 0.1 μm < Ø < 2.5 μm. Mainly originate from man-made sources, such as combustion activities and SOA formation and from coagulation of the nucleation mode**

# Processes involved in aerosol formation for the accumulation mode

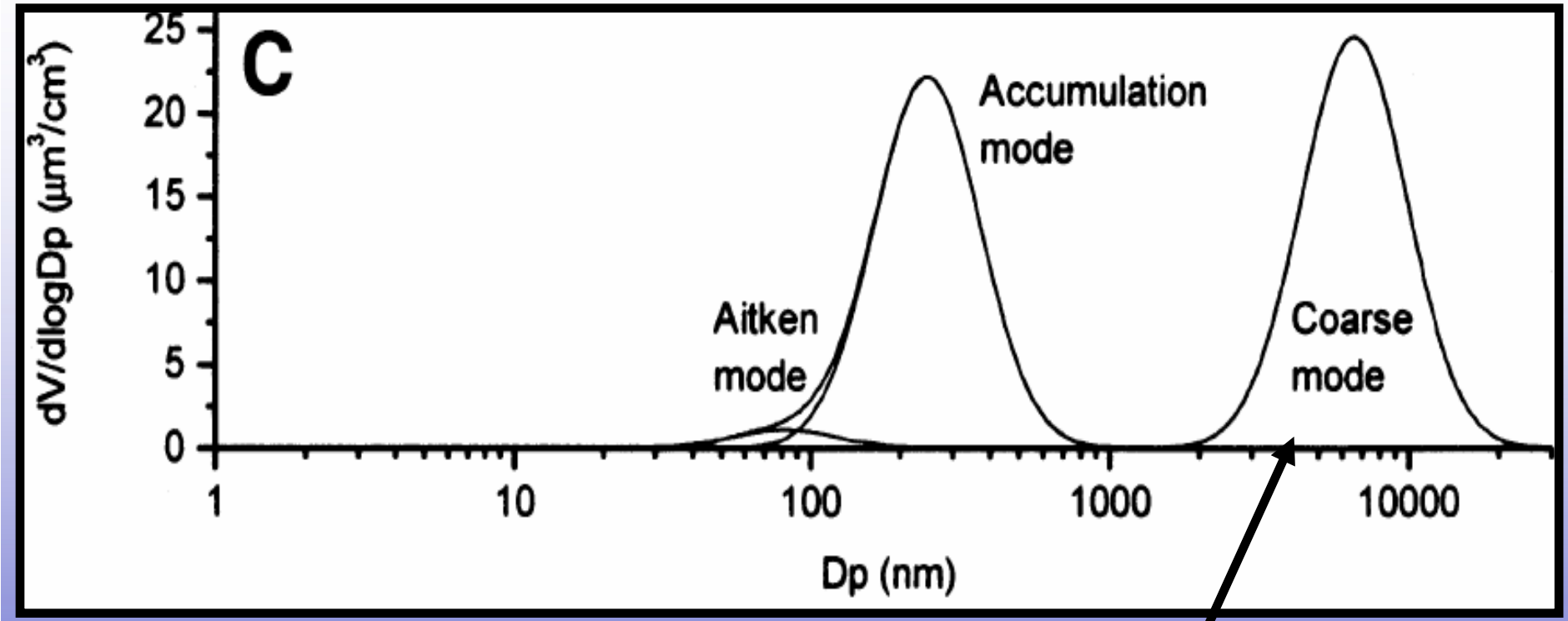
- **Coagulation of nucleation mode particles**

- **Gas-particle partitioning:** condensation of compounds, even at concentration under the saturation concentration

$$PM + X_{(g)} \longrightarrow X_{ads}$$

- Compound either adsorbed on the surface or absorbed in the particle
- Partitioning is a function of saturation vapor pressure, particle concentration and temperature

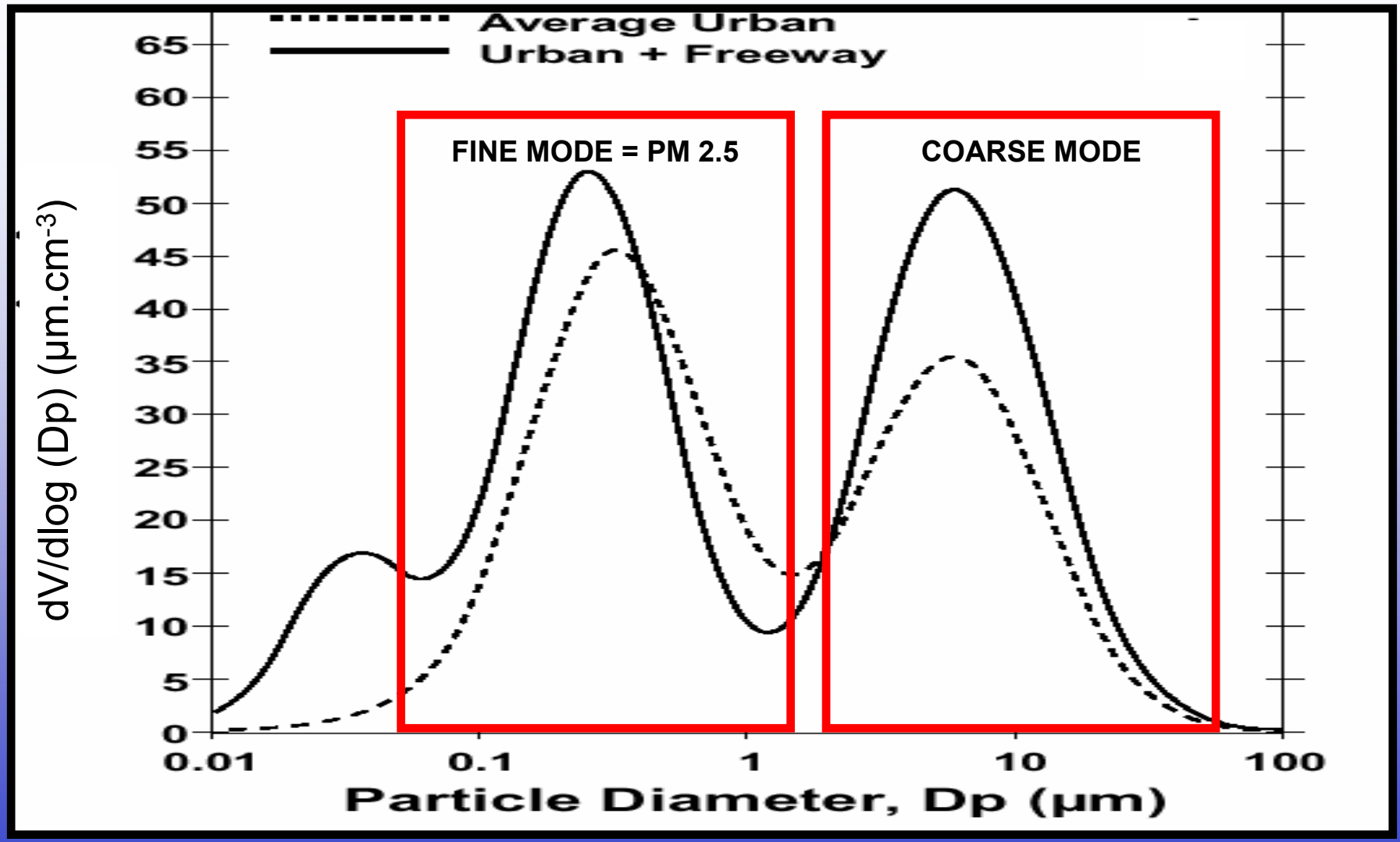
# Classification of atmospheric aerosols




**3. The coarse mode : 2.5 µm < Ø**

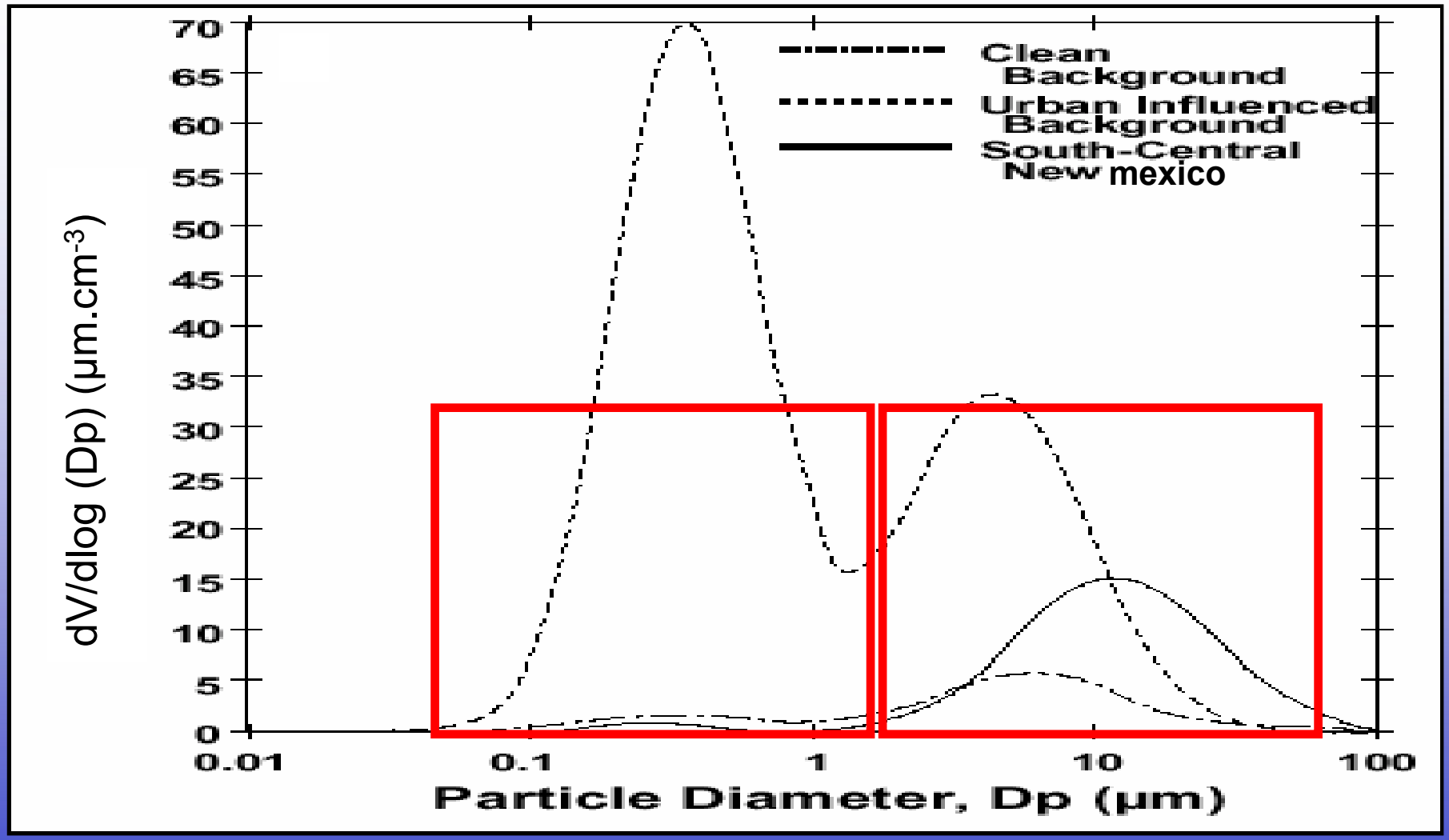
**Originate from natural sources, such as dust, sea spray, volcanoes**

# Classification of atmospheric aerosols




**Nucleation mode generally absent in the urban atmosphere**

# Classification of atmospheric aerosols




**Importance of the fine and coarse modes varies widely with the considered area**

# Atmospheric aerosols : Summary

Suspension of solid or liquid in the atmosphere

- Wide range of size : from 1 nm to 100 µm
- 2 main classes : **fine** (Ø < 2.5 µm) (PM2.5) and **coarse** (Ø > 2.5 µm) when considering surface area and volume/mass
- **Fine** particles mainly **man-made** and **coarse** particles mainly **natural**
- Wide range of concentrations : from 1 to 100 $\mu g.m^{-3}$ according to site location and time