**ATM515 Aerosol Physics**

Lecture 3: Characterization of aerosols
Part I

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## How do we characterize aerosols?

- **Concentrations:**
  - **Number concentration by counting (CN, CCN)**
  - **Mass concentration by weight measurement (PM2.5, PM1)**
- **Sizes: Size distributions (SMPS, etc)**
- Compositions (AMS)
- Optical properties (sun photometers, nephelometers, etc.)

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Example:

Particles in typical air in Albany, NY:

$N = 4{,}000\ \#/cm^3$
$M = 3.14\ \mu g/m^3$
$Dp = ???$ Assuming particle density = $1.5\ g/cm^3$

Particles in typical air in New York City, NY:

$N = 32{,}000\ \#/cm^3$
$M = 3.14\ \mu g/m^3$
$Dp = ???$ Assuming particle density = $1.5\ g/cm^3$

Q: Does this mean all the particles in 1 $cm^3$ air have the same size? How can we better describe this aerosol system?

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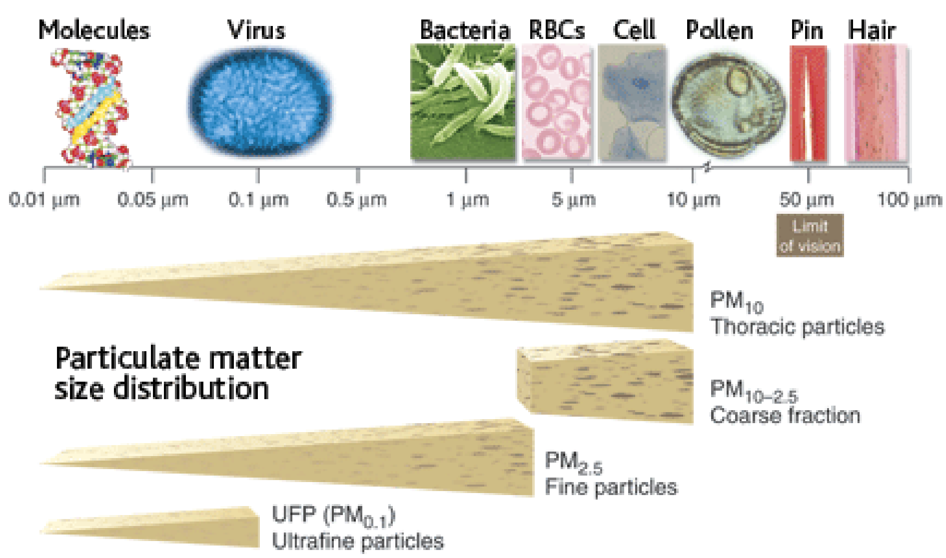


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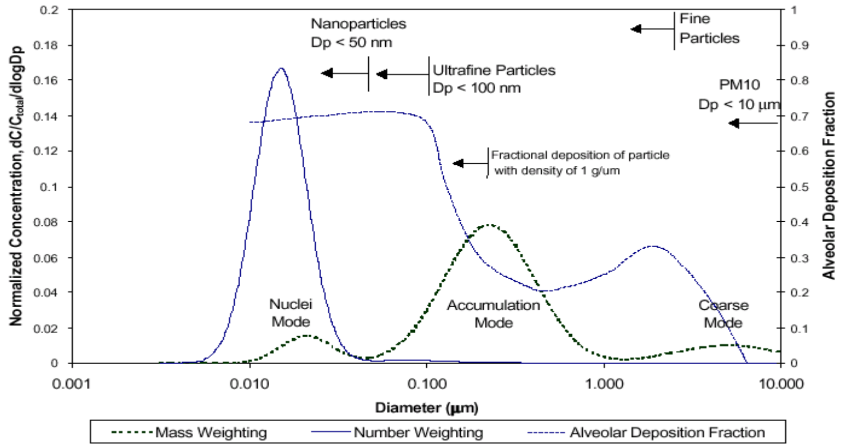
## Typical Diesel Particle Size Distribution




From Kittelson et al, 2000.

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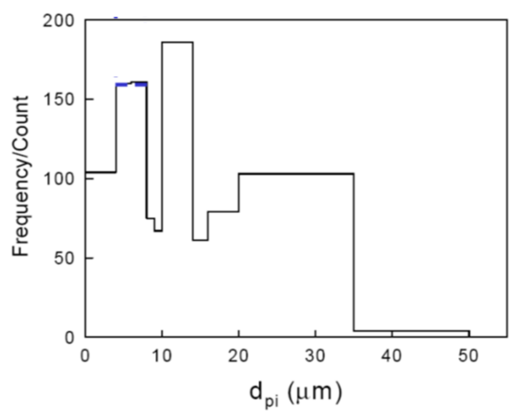
## Histogram of frequency (count) versus particle size

| Size Range (µm) | Count (#) |
|---|---|
| 0-4 | 104 |
| 4-6 | 160 |
| 6-8 | 161 |
| 8-9 | 75 |
| 9-10 | 67 |
| 10-14 | 186 |
| 14-16 | 61 |
| 16-20 | 79 |
| 20-35 | 103 |
| 35-50 | 4 |
| > 50 | 0 |
| Total | 1000 |




**Q: Which size range has the most particles?**

**Q: See any problem in this approach of describing particle size distributions?**

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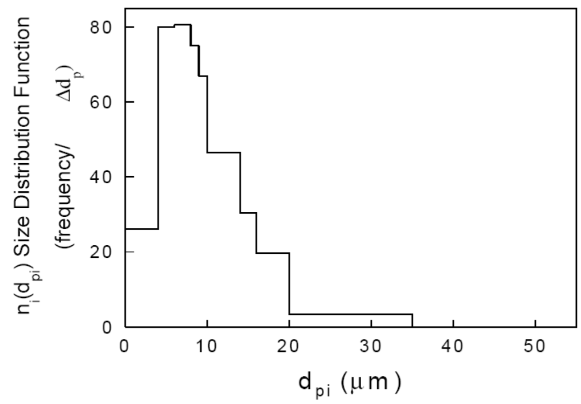
## Frequency/$\Delta d_p$ (distribution function) vs particle size

| Size Range (µm) | Count/$\Delta d_{pi}$ (#/µm) |
|---|---|
| 0-4 | 26 |
| 4-6 | 80 |
| 6-8 | 80.5 |
| 8-9 | 75 |
| 9-10 | 67 |
| 10-14 | 46.5 |
| 14-16 | 30.5 |
| 16-20 | 19.25 |
| 20-35 | 6.87 |
| 35-50 | 0.27 |
| > 50 | 0 |




$$n_i = \frac{Count_i}{\Delta d_{pi}}$$

**Q: Total # of particles ?**

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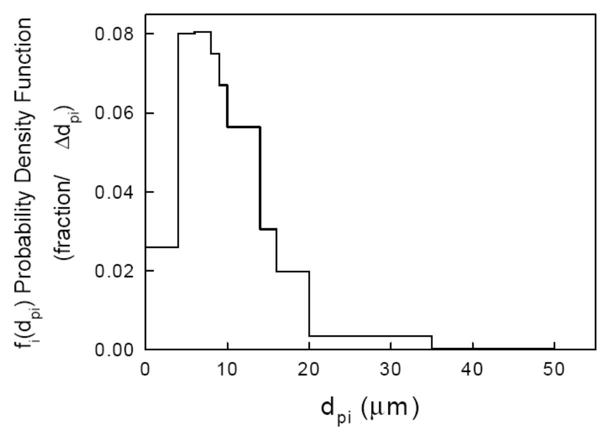
## Standardized frequency/$\Delta d_p$ vs particle size

| Size Range (µm) | Fraction/size (1/µm) |
|---|---|
| 0-4 | 0.026 |
| 4-6 | 0.08 |
| 6-8 | 0.0805 |
| 8-9 | 0.075 |
| 9-10 | 0.067 |
| 10-14 | 0.465 |
| 14-16 | 0.0305 |
| 16-20 | 0.0197 |
| 20-35 | 0.0034 |
| 35-50 | 0.0001 |
| > 50 | 0 |




$$f_i = \frac{n_i}{N}$$

**Q: What is the value of the total area under the line?**

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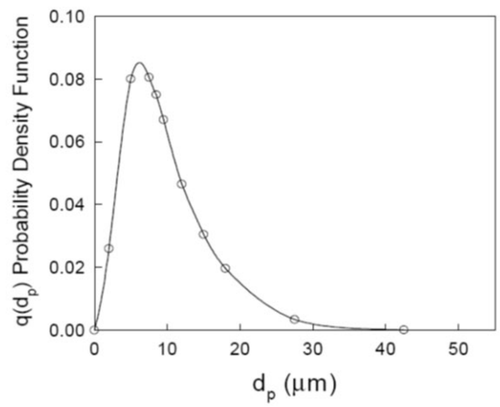
## Continuous Particle Size Distribution

If the size range is very small, the discrete PSD will approach **continuous PSD**.

$$q(d_p) = \left.\frac{\Delta f_i}{\Delta d_{pi}}\right|_{\Delta \to 0} = \frac{df}{dd_p}$$

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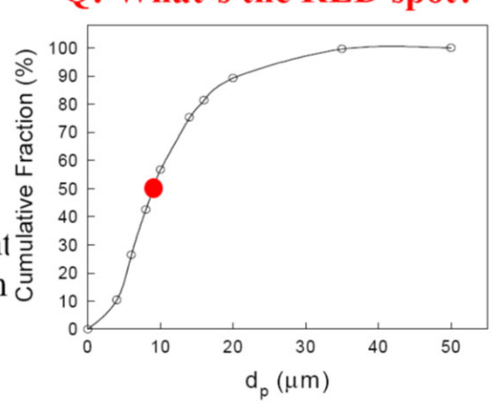
## Cumulative Distribution

- Definition:
  - The fraction that is less than a specific size $F(a) = \int_0^a q(d_p)dd_p$
- Why cumulative distribution?
  - Can be used to determine some statistical values. Provide another viewpoint to observe the distribution

**Q: What's the RED spot?**




$q(d_p)$: $q$ as a function of $d_p$

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## Particle Size Distribution

- Monodisperse - All the particles are of the same size
- Polydisperse - Particles are of more than one size (more realistic)

Typical data from measurement

| Size Range (μm) | Count (#) | Fraction | Percent (%) | Cumulative Percent (%) | Fraction/size ($\mu m^{-1}$) |
|---|---|---|---|---|---|
| 0-4 | 104 | 0.104 | 10.4 | 10.4 | 0.026 |
| 4-6 | 160 | 0.16 | 16.0 | 26.4 | 0.08 |
| 6-8 | 161 | 0.161 | 16.1 | 42.5 | 0.0805 |
| 8-9 | 75 | 0.075 | 7.5 | 50.0 | 0.075 |
| 9-10 | 67 | 0.067 | 6.7 | 56.7 | 0.067 |
| 10-14 | 186 | 0.186 | 18.6 | 75.3 | 0.465 |
| 14-16 | 61 | 0.61 | 6.1 | 81.4 | 0.0305 |
| 16-20 | 79 | 0.79 | 7.9 | 89.3 | 0.0197 |
| 20-35 | 103 | 0.103 | 10.3 | 99.6 | 0.0034 |
| 35-50 | 4 | 0.004 | 0.4 | 100.0 | 0.0001 |
| > 50 | 0 | 0 | 0 | 100.0 | 0 |
| Total | 1000 | | 100.0 | | |

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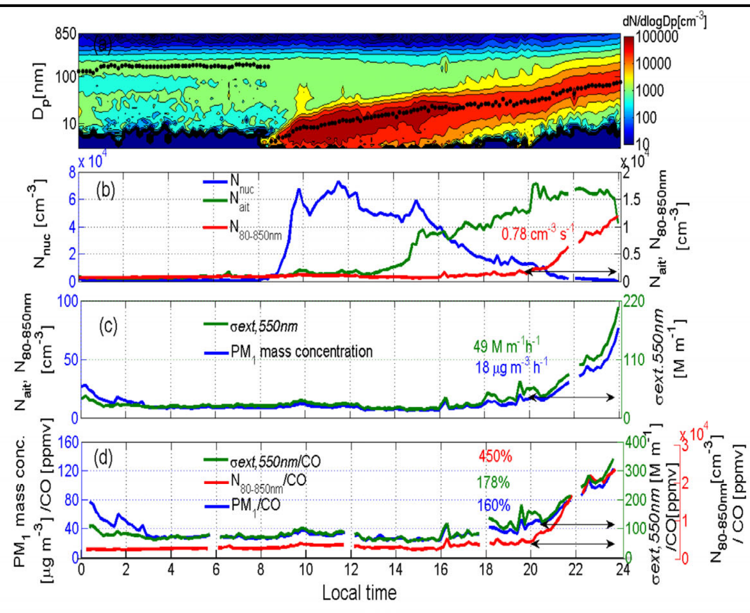


**Fig. 9.** The number size distribution at SDZ on 13 March 2008 and mode diameter (dots) **(a)**, evolution of the $N_{nuc}$, $N_{ait}$ and $N_{80-850nm}$ respectively **(b)**, evolution of $\sigma_{ext,550nm}$, extinction coefficient at 550 nm and $PM_1$ mass concentration calculated from TDMPS data **(c)** and the normalized $N_{80-850nm}$, $PM_1$ mass concentration and $\sigma_{ext,550nm}$ by the concentration of CO. Shen et al., 2011

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