Atmospheric Aerosols

Lecture 6

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Size and Morphology

More descriptors according to the same principles

Name	Definition	Formula
Volume diameter	Diameter of a sphere having the same volume as the particle	$V = \pi d^3 / 6$
Surface diameter	Diameter of a sphere having the same surface as the particle	$S = \pi d^2$
Surface volume diameter	Diameter of a sphere having the same surface to volume ratio as the particle	$d_{sv} = d_v^3 / 6 d_s^2$
Projected area diameter	Diameter of the circle having the same area as the projection area of particle	$A = \pi d^2 / 4$
Perimeter diameter	Diameter of the circle having the same perimeter as the projection perimeter of particle	$P = \pi d$

The aerosol distribution is more convenient to express as functions of ln(D) or log(D), because particle sizes span several orders of magnitude.

Let's define the number distribution function $n_N^e(D)$ in cm^{-3} as

$n_N^e(\ln(D))d\ln(D)$ = the number of particles per cm^3 of air having diameters in the range ln(D) and ln(D) +d ln(D).

NOTE: We cannot take the logarithm of a dimensional quantity.

Thus, when we write

ln(D) we really mean ln(D/1), where the "reference" particle diameter is 1 μm is not explicitly indicated.

The total number of particles per cm^{-3}, N, is then just

$$N = \int_{-\infty}^{\infty} n_N^e(\ln(D))\, d\ln(D) \qquad (p/cm^3)$$

The surface area and volume distributions as functions of ln(D) can be defined similarly to those with respect to D, as

$$n_S^e(\ln D) = \pi D^2 n_N^e(\ln D) \qquad (\mu m^2 cm^{-3})$$

$$n_V^e(\ln D) = \frac{\pi}{6} D^3 n_N^e(\ln D) \qquad (\mu m^3 cm^{-3})$$

Thus for S and V we have

$$S = \int_{-\infty}^{\infty} n_S^e(\ln D) d\ln D = \pi \int_{-\infty}^{\infty} D^2 n_N^e(\ln D) d\ln D \quad (\mu m^2 cm^{-3})$$

$$V = \int_{-\infty}^{\infty} n_V^e(\ln D) d\ln D = \frac{\pi}{6} \int_{-\infty}^{\infty} D^3 n_N^e(\ln D) d\ln D \quad (\mu m^3 cm^{-3})$$

NOTE: The above aerosol distributions can be also expressed as functions of the base 10 logarithm D, defining

$$n_N^0(\log D), \quad n_S^0(\log D) \quad and \quad n_V^0(\log D)$$

$$n_N\ ,\ n_N^e \ and \ n_N^0 \ are\ different\ mathematical\ functions$$

Thus we have

$$dN = n_N(D)\, dD = n_N^e(\ln(D))\, d\ln(D) = n_N^o(\log(D))\, d\log(D)$$

$$dS = n_S(D)\, dD = n_S^e(\ln(D))\, d\ln(D) = n_S^o(\log(D))\, d\log(D)$$

$$dV = n_V(D)\, dD = n_V^e(\ln(D))\, d\ln(D) = n_V^o(\log(D))\, d\log(D)$$

Based on that notation, the various size distribution are

$$n_N(\mathrm{D}) = \frac{dN}{dD} \qquad n_N^e(\ln \mathrm{D}) = \frac{dN}{d\ln D} \qquad n_N^0(\log D) = \frac{dN}{d\log D}$$

$$n_S(\mathrm{D}) = \frac{dS}{dD} \qquad n_S^e(\ln \mathrm{D}) = \frac{dS}{d\ln D} \qquad n_S^0(\log D) = \frac{dS}{d\log D}$$

$$n_V(\mathrm{D}) = \frac{dV}{dD} \qquad n_V^e(\ln \mathrm{D}) = \frac{dV}{d\ln D} \qquad n_V^0(\log D) = \frac{dV}{d\log D}$$

Relating Size Distributions Based on Different Independent Variables

It is often necessary to relate a size distribution based on one independent variable, say, *D*, to one based on another independent variable, say, log *D*. Such a relation can be derived based on (page 27).

The number of particles *dN in* an infinitesimal size range *D* to *D+ dD* is the same regardless of the expression used for the description of the size distribution function. Thus in the particular case of $n_N(D)$ and $n^{\circ}_N(\log D)$

$$n_N(D)\, dD = n_N^{\circ}(\log(D))\, d\log(D)$$

Since $d\log(D) = d\ln(D) / 2.303 = dD / 2.303\, D$, we can relate the distributions above as:

$$n_N(D)\,dD = n_N^{o}(\log(D))\,d\log(D)$$

Since $d\log(D) = d\ln(D)/2.303 = dD/2.303D$, we can relate the distributions above as:

$$n_N^{o}(\log(D)) = 2.303\,D\,n_N(D)$$

$$n_S^{o}(\log(D)) = 2.303\,D\,n_S(D)$$

$$n_V^{o}(\log(D)) = 2.303\,D\,n_V(D)$$

The distributions with respect to D are related to those with respect to $\ln D$ by

$$n_N^{e}(\ln(D)) = D\,n_N(D)$$

$$n_S^{e}(\ln(D)) = D\,n_S(D)$$

$$n_V^{e}(\ln(D)) = D\,n_V(D)$$

The normalized distribution functions based on log D for surface area and volume are similar. For the differential number of particles between D and D + dD we use the notation dN, and likewise dS and dV, we can represent the size distribution functions as -

$$n_N\,(\log D) = \{dN\} \,/\, \{d\log D\}$$

$$n_s\,(\log D) = \{dS\} \,/\, \{d\log D\}$$

$$n_v\,(\log D) = \{dV\} \,/\, \{d\log D\}$$

This is the common notation for expressing the variation in particle number, surface area or volume with the log of the diameter.

$$n_N(\mathrm{D}) = \frac{dN}{dD} \qquad n_N^e(\ln \mathrm{D}) = \frac{dN}{d\ln D} \qquad n_N^0(\log D) = \frac{dN}{d\log D}$$

Log-normal distributions

Number distribution →

$$n_N^e(\ln D) = \frac{dN}{d\ln D}$$

Surface area distribution →

$$n_S^e(\ln D) = \frac{dS}{d\ln D}$$

Volume distribution →

$$n_V^e(\ln D) = \frac{dV}{d\ln D}$$

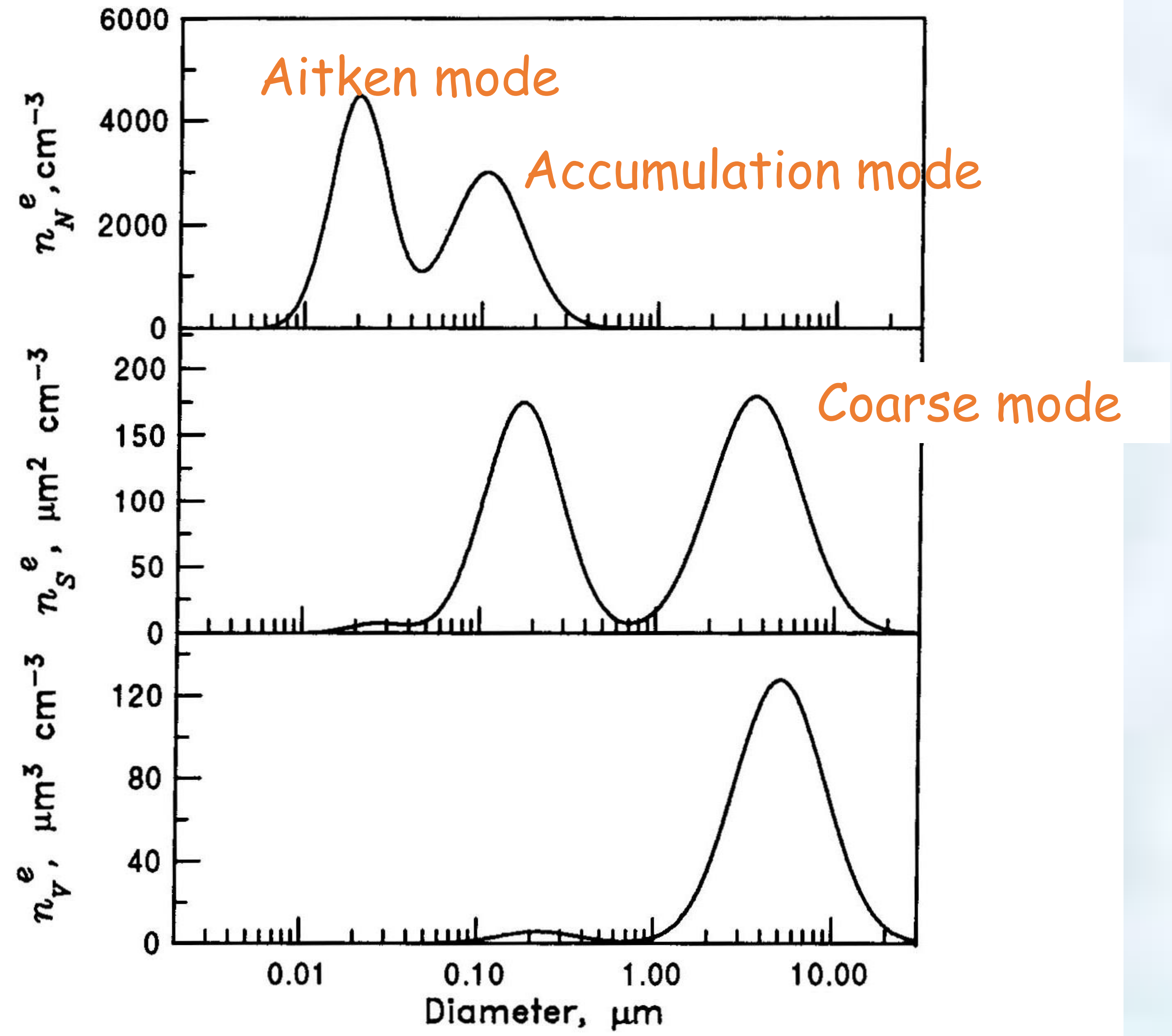


FIGURE 7.6 The same aerosol distribution as in Figures 7.4 and 7.5 expressed as a function of log D_p and plotted versus log D_p. Also shown are the surface and volume distributions. The areas below the three curves correspond to the total aerosol number, surface, and volume, respectively.

formation of aerosol particles by gas-to-particle conversion

The formation of aerosol particles by gas-to-particle conversion take place through the following mechanisms (Hameri et al., 1996).

Reaction of gases to form low vapour pressure products

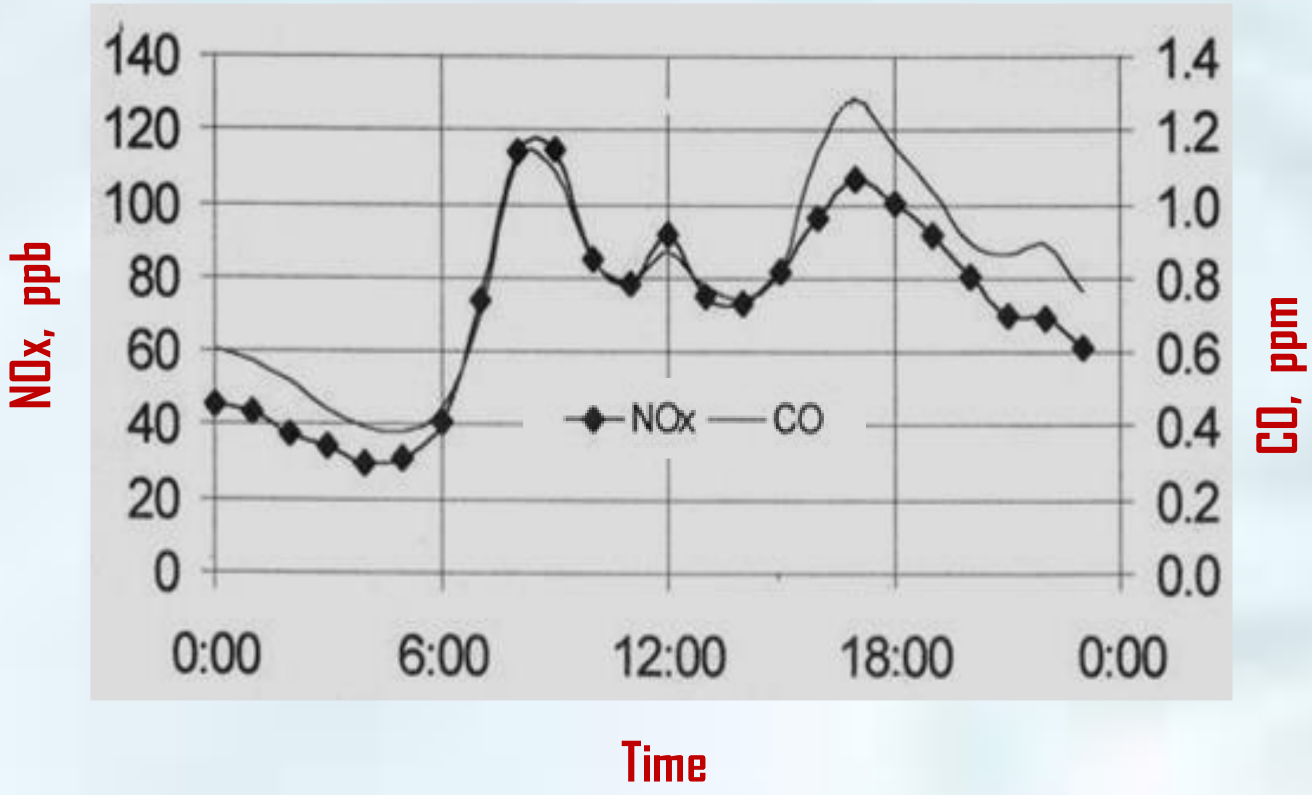
Nucleation of these low vapour pressure products

The condensation of vapours to the surface of particle

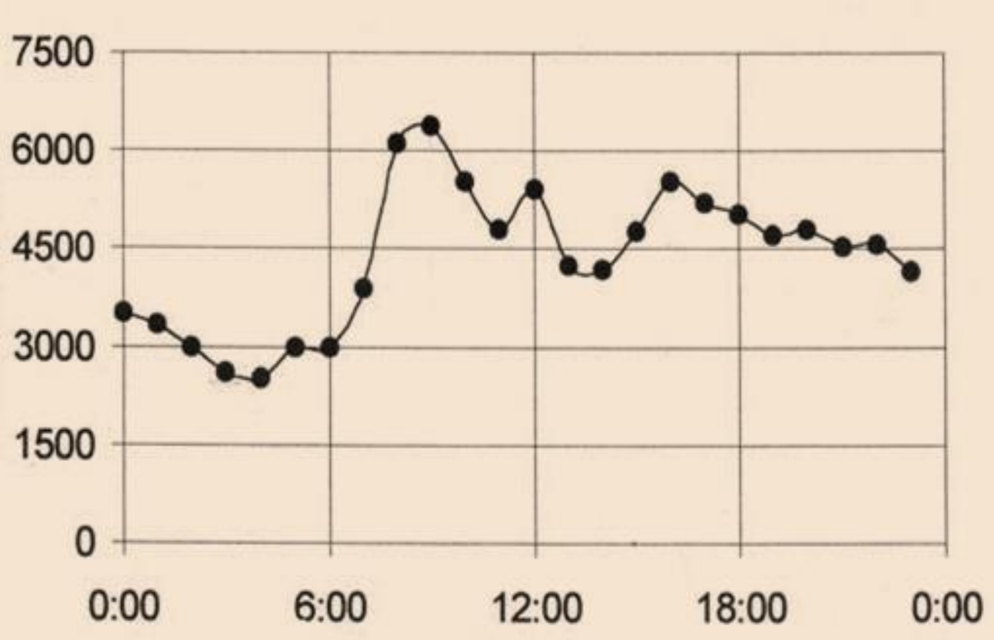
Reaction of gases with the surfaces of existing particle

Chemical reaction within particle.

Hourly averaged NOx and CO concentrations from Manchester City Centre



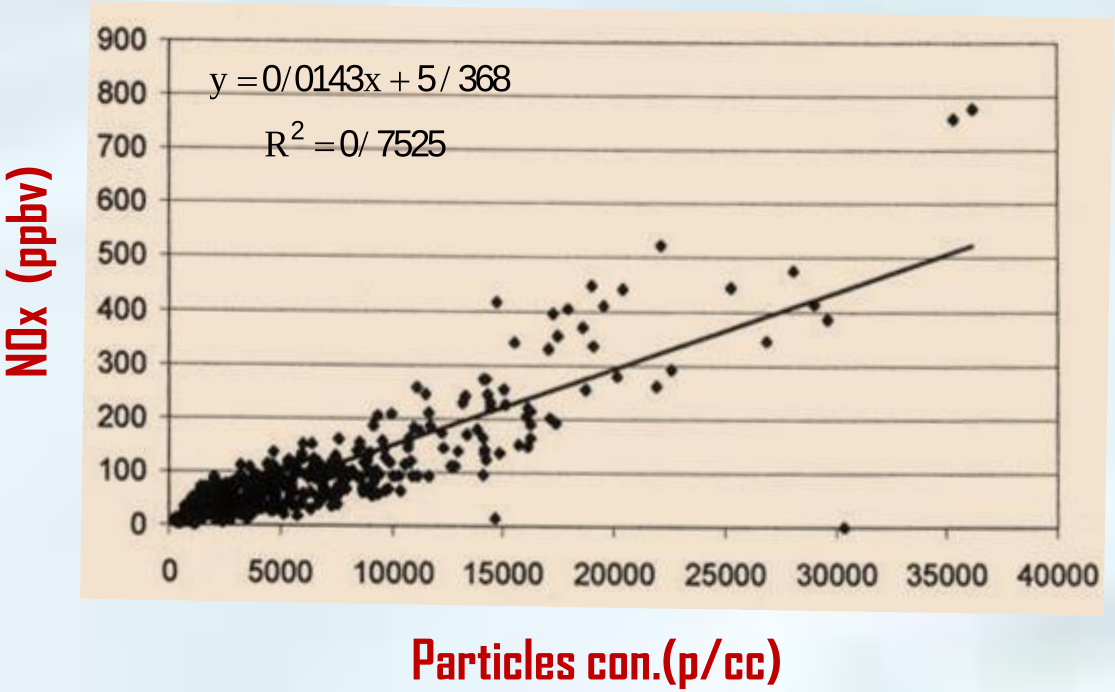
Accumulation Mode (100 - 500 nm)



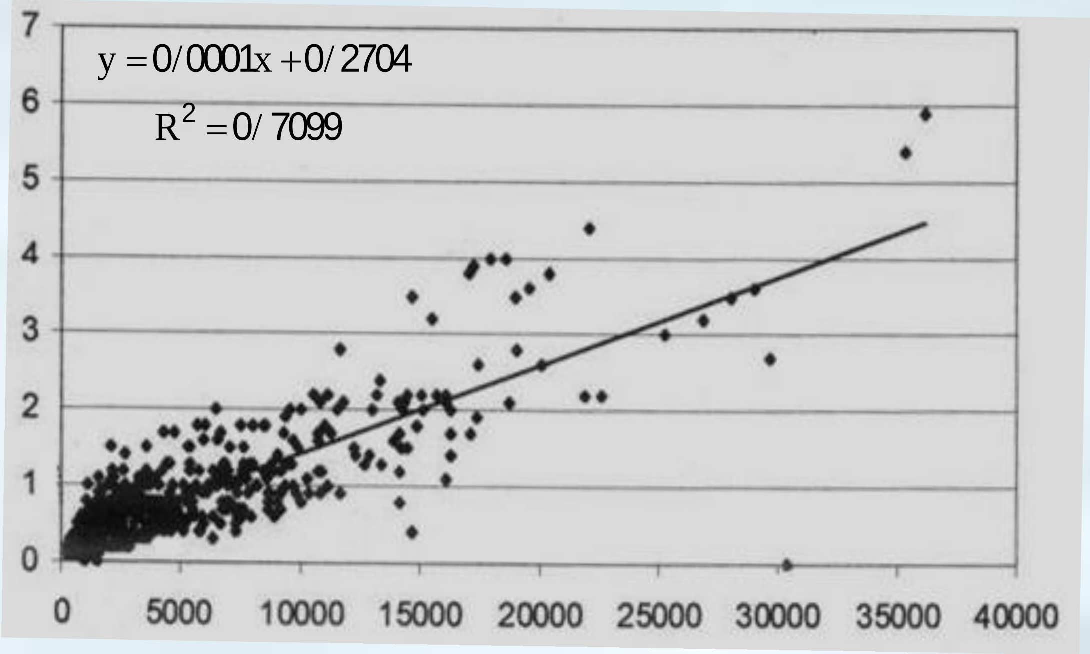
concentration (p/cc)

Time

Accumulation Mode (100 - 470 nm)



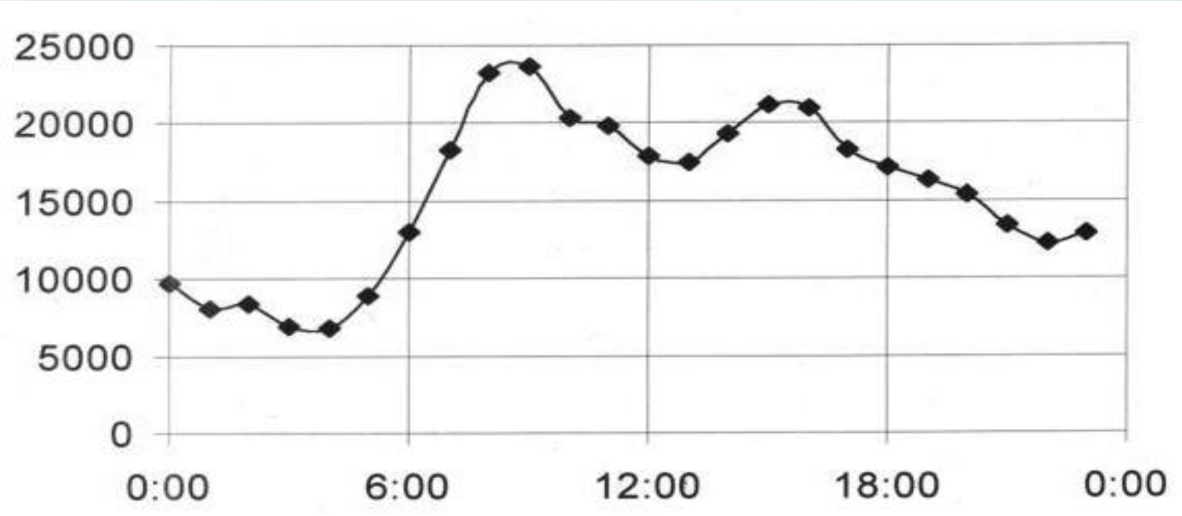
Accumulation Mode (100 - 470 nm)



CO (ppmv)

Particles Con.(p/cc)

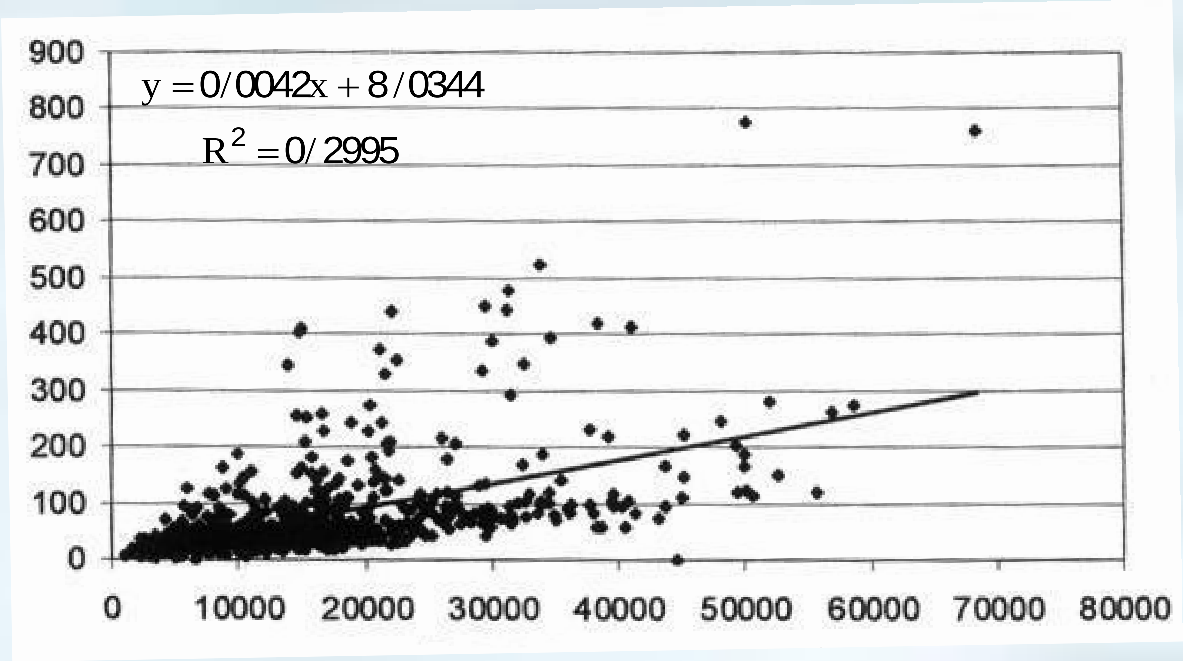
Aitken mode (13 - 30 nm)



Concentration (p/cc)

Time

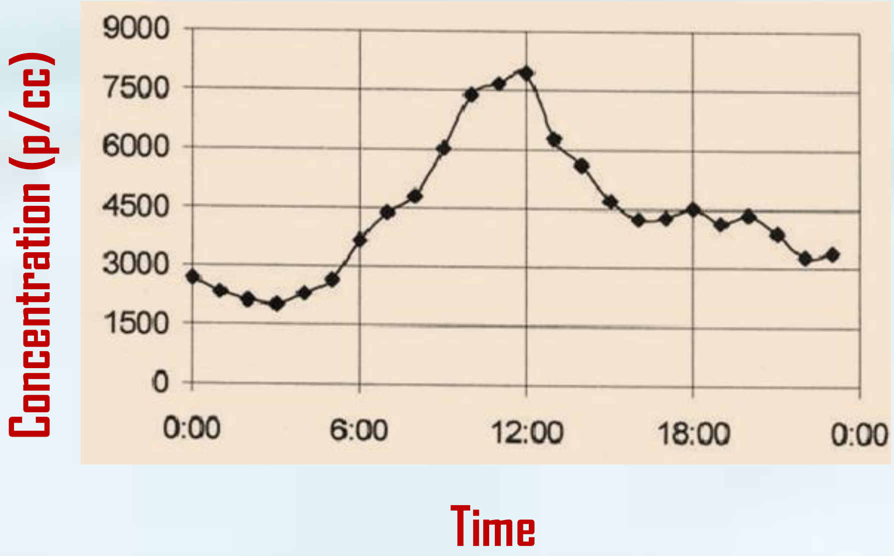
Aitken mode (13 - 30 nm)

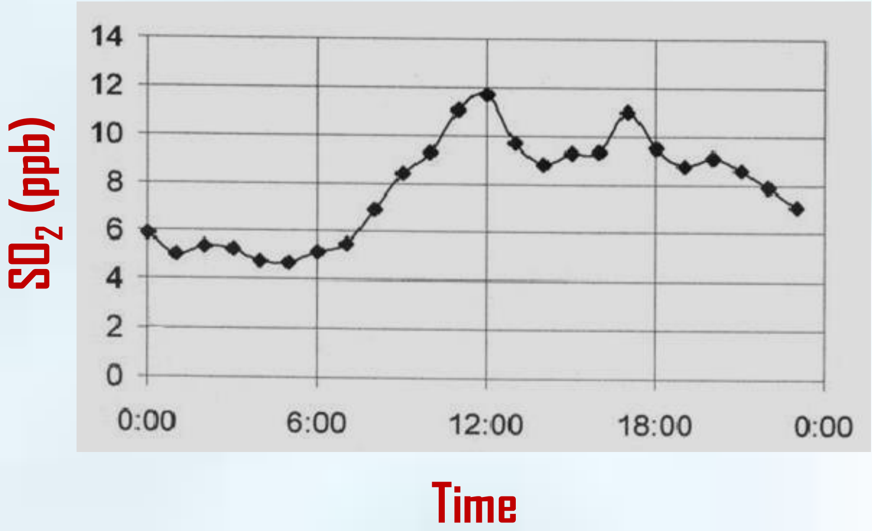


NOx (ppbv)

Particles Con. (p/cc)

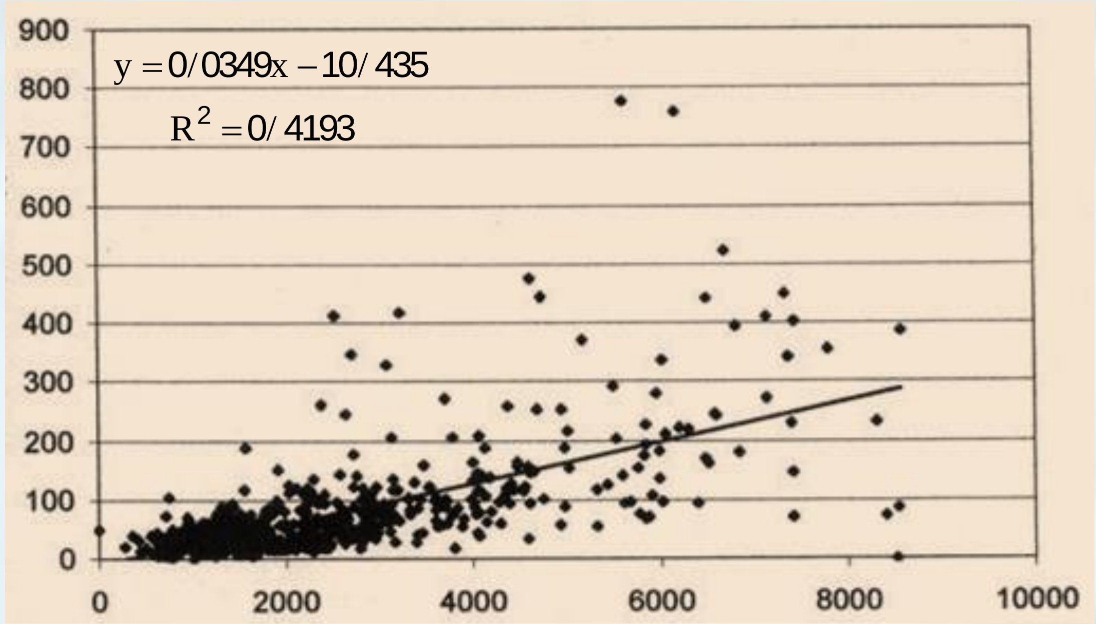
Ultrafine Mode (3 - 8 nm)





Mode (100 - 3000 nm)

NOx (ppbv)



Particles Con.(p/cc)