NEW ZEALAND BRANCH SEMINAR
Friday 12 June, 2015 – Auckland, NZ

An introduction to Aerosol Science

Elizabeth Somervell, Mike Harvey, Ian Longley and Guy Coulson
National Institute of Water & Atmospheric Research
Auckland, New Zealand

An introduction to Aerosol Science

2.00	Introduction – Guy
2.15	The ever changing life of a particle - Elizabeth
2.30	Natural Terrestrial Sources - Ian
2.45	Natural Marine Sources – Mike
300	break
3.15	Anthropogenic Sources – Guy
3.30	Characterisation of urban aerosol – Elizabeth
3.45	Urban sinks and impacts – Ian
4.00	The aging process - Mike
4.15	Recap and questions- All
4.30	end

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An introduction to Aerosol Science

Introduction

Guy Coulson

National Institute of Water & Atmospheric Research

Auckland, New Zealand

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History

Definitions

Formation processes

Size and shape – they're all different

Different descriptions of aerosols

Lifetimes

Removal processes

Health effects

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Brief History of Aerosol Science

"Whosoever shall be found guilty of burning coal shall suffer the loss of his head."
Edward II. Circa 1300

Claude Monet. The Houses of Parliament (Effect of Fog), 1903-1904

Major investigators/Applications

1869 Tyndall - detectors, light scattering

1871 Kelvin - nucleation

1885 Aitken, atm aerosols, CN counters

(Aitken pocket counter used >50 yrs), 1st to investigate photochemical pollution, proved sulphurous gas from coal combustion produced air pollution.

1905 Einstein, diffusion and Brownian motion

1908 Mie, light scattering by small particles.

1917 Smoluchowski, particle coagulation.

1923 Milikan, electrical charge (e)

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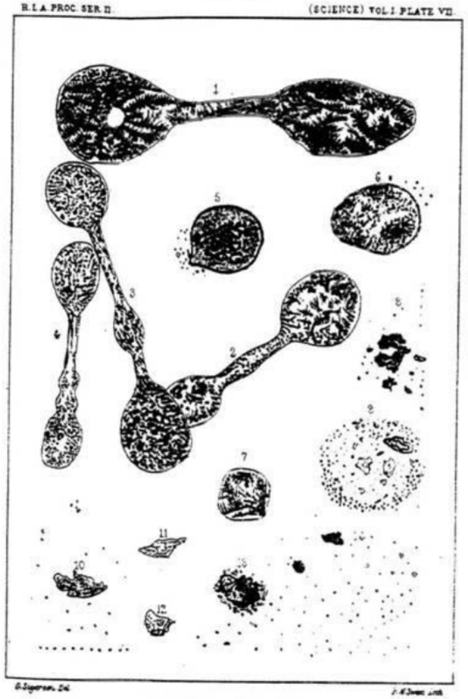
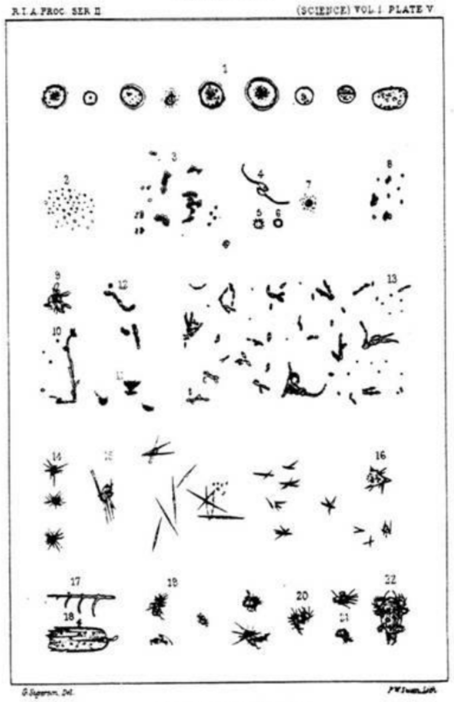
Brief History of Aerosol Science

Sigerson 1870 Proc Roy Irish Acad Sci

City



Country



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Definitions

Aerosols are generally defined as

a colloidal suspension of solid or liquid particles in a gas.

analogy with **sols** – solid particles in a liquid suspension.

The aerosol is the bulk but in general usage, the term aerosol has become synonymous with the particles themselves

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Definitions

Baron and Willeke, [2001] and Colbeck, [1998] classify aerosols according to their physical form and method of generation.

- **Dust –** a solid particle formed by mechanical disintegration by crushing, grinding or blasting of a parent material. Size range from sub micrometre to visible.
- **Fume –** solids produced by physicochemical reactions such as combustion, sublimation or distillation. Typically below 1µm in size.
- **Smoke –** a visible aerosol resulting from incomplete combustion. Typically below 1µm in size.

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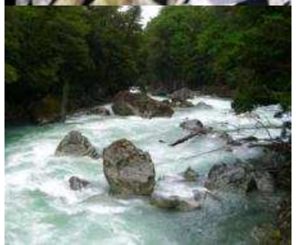
Definitions

Baron and Willeke, [2001] and Colbeck, [1998] classify aerosols according to their physical form and method of generation.

- **Mist and fog –** liquid aerosol produced by the condensation of vapour or by disintegration of larger droplets. Size range from sub micrometre to around 20µm and can coalesce to 100µm.
- **Smog –** a combination of smoke and fog. Consists of products of photochemical reactions. Typically below 1µm in size.
- **Bioaerosol –** solid or liquid aerosol consisting of or containing biologically viable material.



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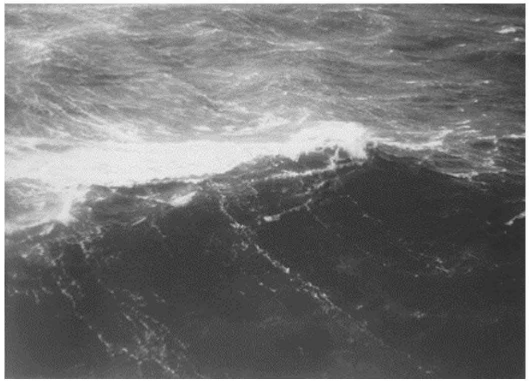
Formation processes

mechanical (geological processes, wind-blown dust, sea salt),
coarse fraction (2.5µm<d<10µm)

biological (pollen, bacteria)

chemical (gas-particle conversion, photochemical reactions, combustion).
ultra-fine fraction (d<100nm).
form as nano-particles (d<20nm) followed by growth through agglomeration to the accumulation mode (d≈100-300nm)

In urban areas, combustion particles, particularly those from traffic are the predominant source of ultra-fine-particles (UFP)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Formation processes

How much?

Sources	Emission Tg yr^{-1},	Lower limit Tg yr^{-1}	Upper limit Tg yr^{-1}	Column burden mg m^{-2}	Contribu on to Optical depth
Natural					
Primary					
Soil dust	1500	100	2000	32.2	0.023
Sea-salt	1300	300	10000	7	0.003
Volcanic dust	33	25	300	0.7	0.001
Biological debris	50	3	150	1.1	0.002
Secondary					
Sulphates	150	85	1100	2.8	0.014
Organics	55	15	200	2.1	0.011
Nitrates	30	15	700	0.5	0.001
Total Natural	3118	543	14450	46.4	0.055
Anthropogenic					
Primary					
Industrial dust	100	10	170	2.1	0.004
Black carbon	20	3	150	0.6	0.006
Secondary					
Sulphates	140	70	375	3.8	0.019
Biomass burning (w/o BC)	90	60	150	3.4	0.017
Nitrates	40	23	65	0.8	0.002
Organic matter	10	5	90	0.4	0.002
Total Anthropogenic	400	171	1000	11.1	0.05
Total	**3518**	**714**	**15450**	**57.5**	**0.105**
Anthropogenic fraction (%)	11	24	6	19	48

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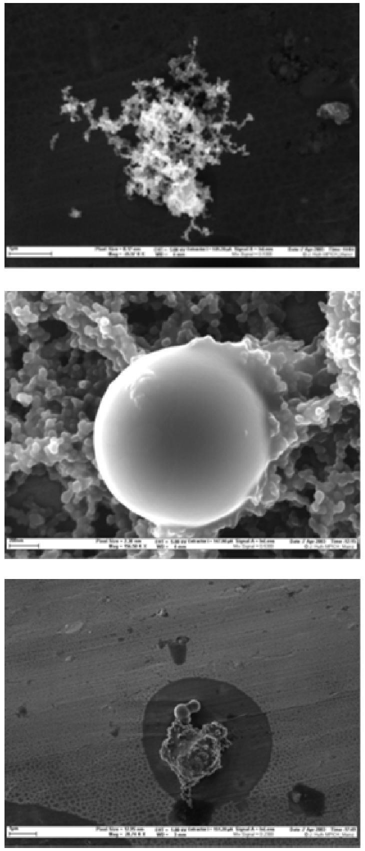
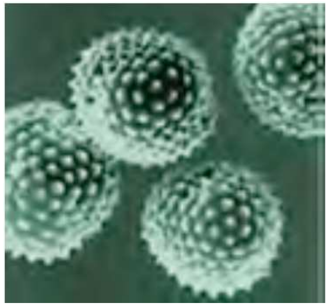
Size and shape – they're all different



woodsmoke

sea salt



pollen

soot

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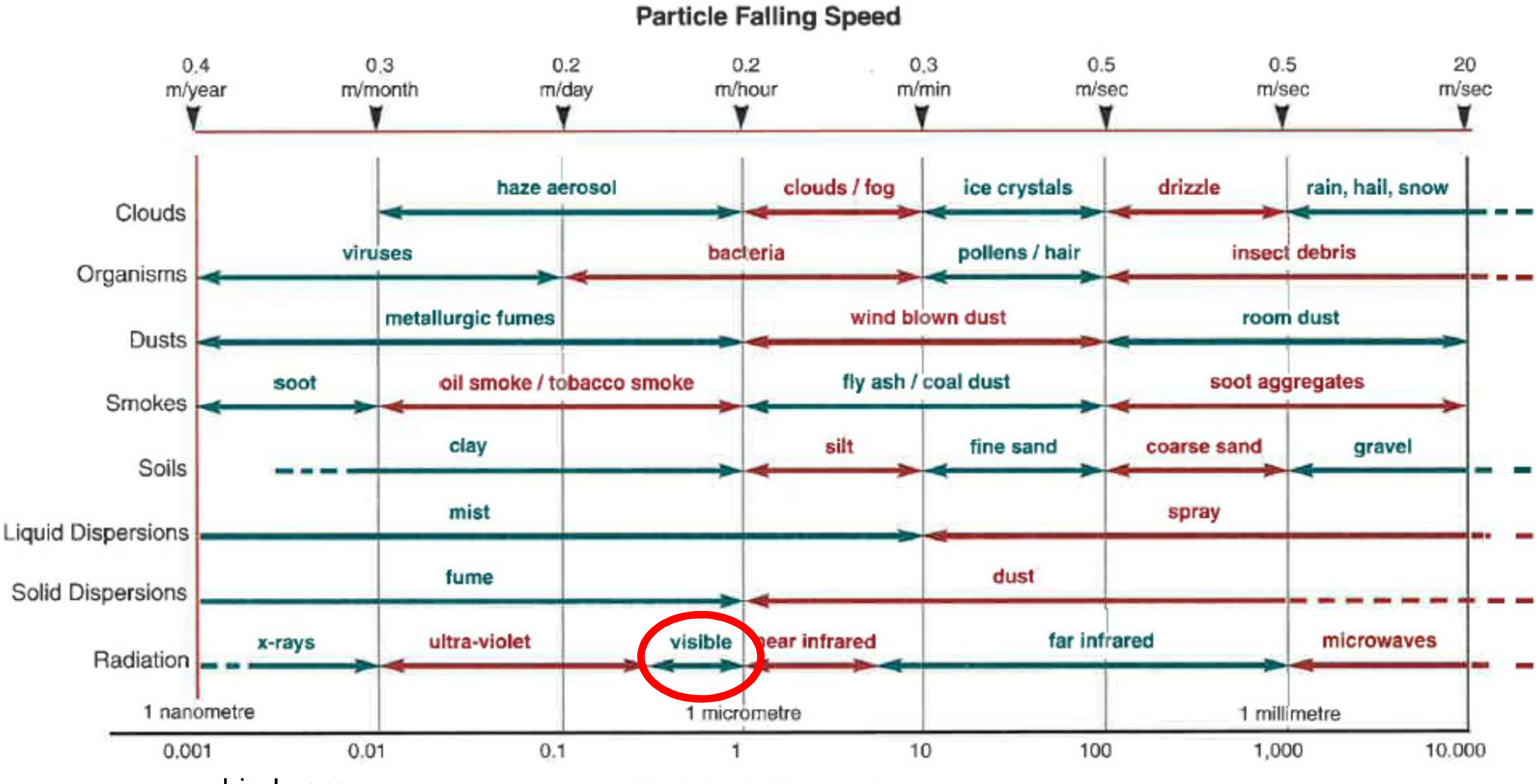
Size and shape – they're all different

From molecules to visible



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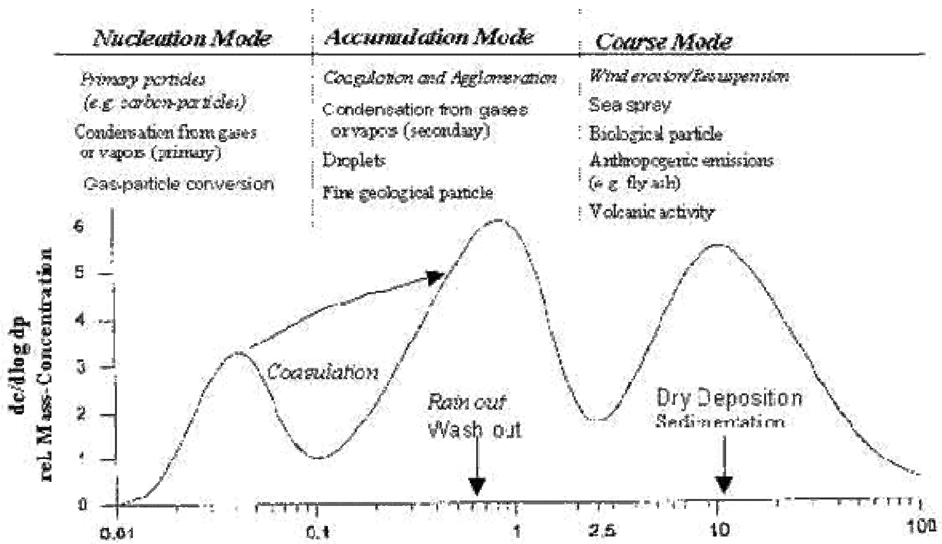
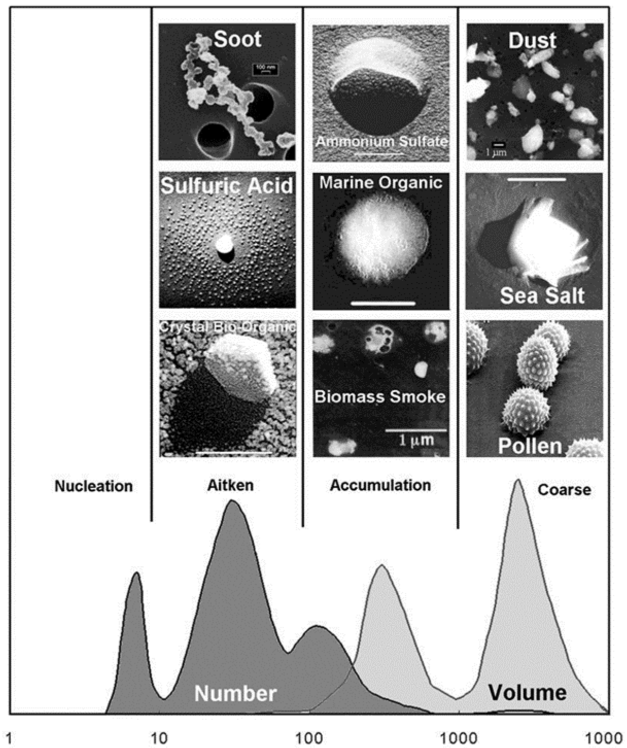
Size and shape – they're all different

The size distribution





Heintzenberg et al

Always log-normal

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Different descriptions

Particle size
Diameter of individual particle

Particle number concentration
Number of particles per unit volume (#/cm^3)

Particle size distribution
Range of sizes in a sample

Particle Mass concentration
Mass of particles per unit volume (µg/cm^3, ng/cm^3)

Source or composition
Black Carbon, Brown Carbon, marine, diesel etc

Mixing state
Mixtures of particles

Optical Depth
Absorbing and scattering

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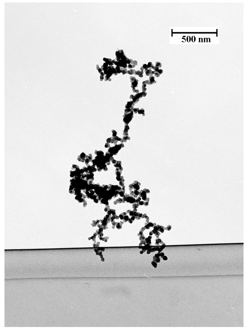
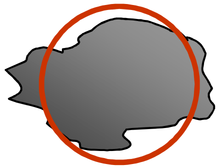
Different descriptions

What is “size”?

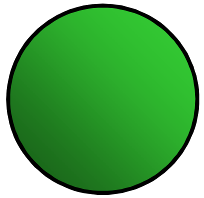


“equivalent diameter” equates a particular property of a particle to the diameter it would have if it were spherical and of even density.

Volume Equivalent Diameter



Aerodynamic equivalent sphere



(fractal diameter)

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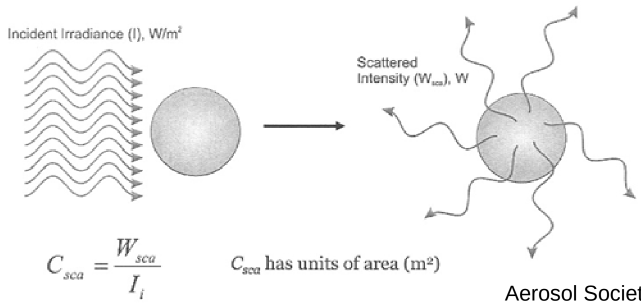
Different descriptions

Common forms of equivalent diameter



Aerosol Society

- Aerodynamic diameter
  - Cyclone type inlets
  - APS (Aerodynamic Particle Sizer)

- Light scattering equivalent diameter (Optical cross section)
  - Grimm aerosol spectrometer
  - Passive Cavity Aerosol Spectrometer Probe (PCASP)

- Electrical mobility equivalent diameter
  - Scanning Mobility Particle Sizer (SMPS … a.k.a. Differential Mobility Analizer – DMA)

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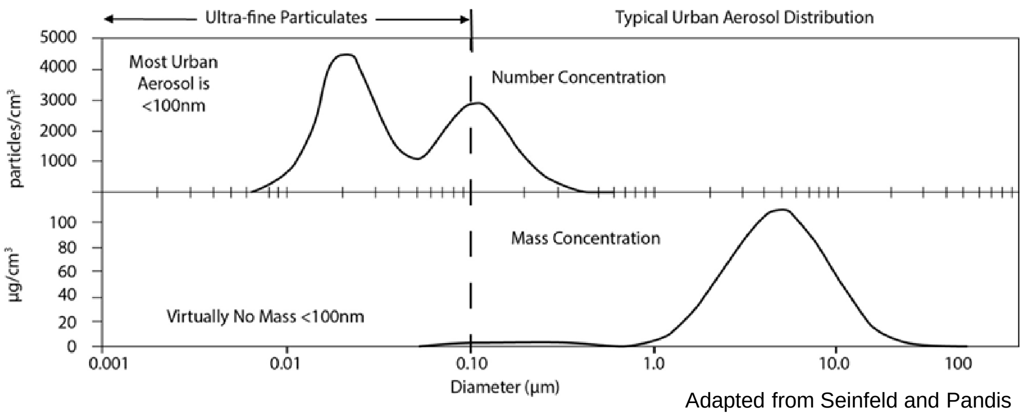
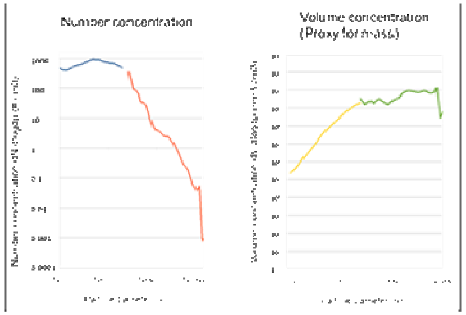
Different descriptions

Number vs Mass

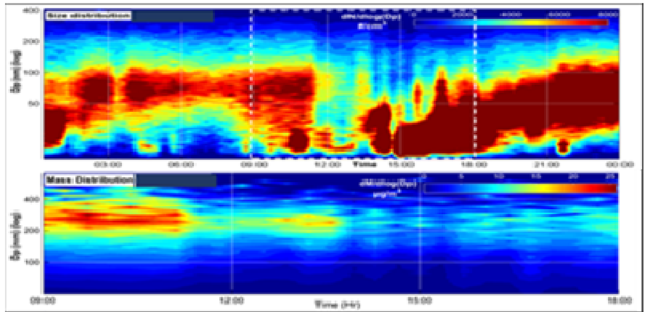


Adapted from Seinfeld and Pandis

Real-life examples



particle size distribution from Otahuhu roadside (SH1)



And from Prague

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Different descriptions

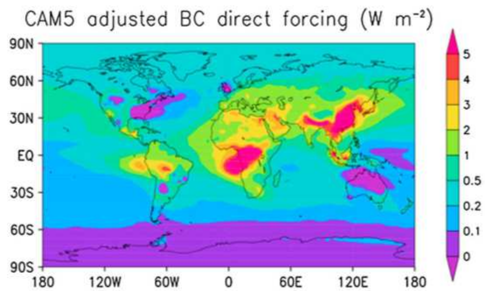
Black Carbon (BC)

Also referred to as Elemental Carbon (EC) or Soot

Also in UFP range

Expressed as mass in *ng/m³*

Marker for diesel particles
(as long as you can…)



"brown carbon"
- sugars
- alcohols
- aromatics
- di/tri acids
- ketoacids
- hydroxyacids

Differentiate between fossil carbon and biomass carbon (Brown Carbon)

1. **Uv absorption at 370nm and 880nm (Delta BC)**
2. **Z ratio = BC/CO2**

potential long-term effect on Global Warming as high as 1600 times CO_2
biomass burning is estimated to contribute 20% of global Black Carbon

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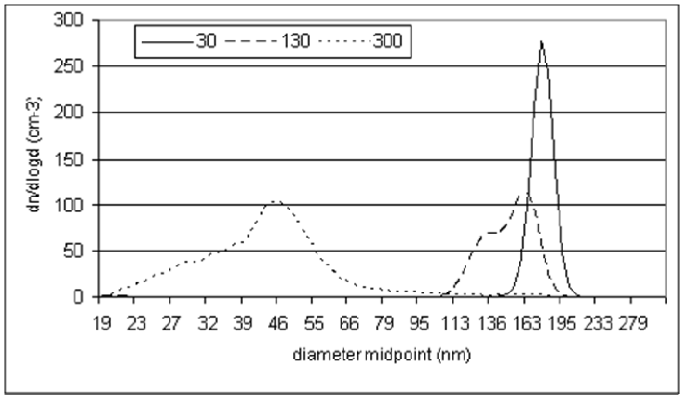
Different descriptions

External vs Internal mixing



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Lifetimes and ranges

Aitken nuclei – hours to days (diffusion/coagulation)
Accumulation mode – weeks
Coarse mode – hours to days (deposition)
Ultrafine – minutes to hours

Classification	Range of distances	Range of times
Local	0 – 10km	1 hour – 1 day
Urban	10 – 100km	1 hour – 1 day
Long-range		
Mid-range	100 – 250km	3 hours – 1 day
Regional	250 – 1000km	8 hours – 4 days
Continental	1000 – 5000km	1 day – 2 weeks
Global	5000 – 40,000km	> 2 weeks

Saharan dust found in US
Lead from Roman workings in Greenland ice cores
Lead from industrial revolution in Antarctic ice cores

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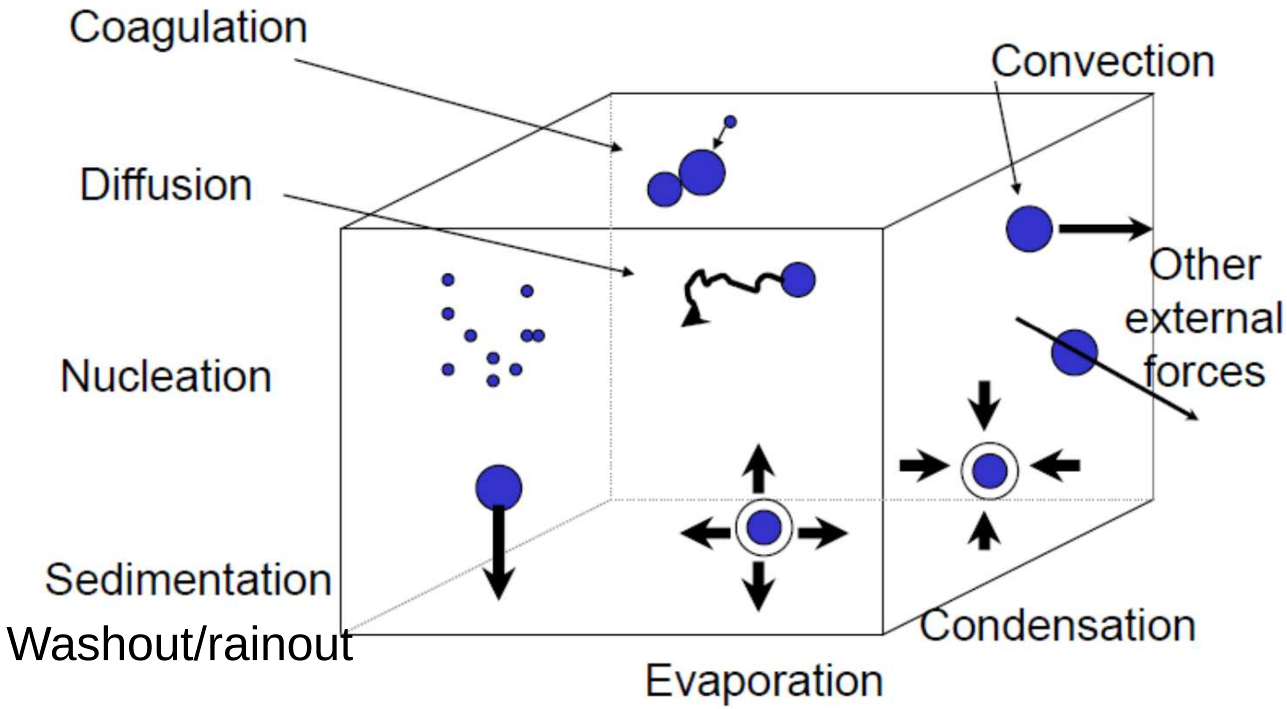
Removal processes



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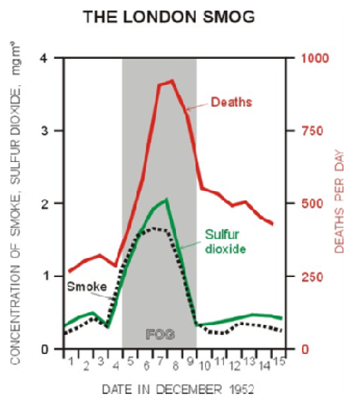
Health effects

traditional assessment – fixed point monitors - associations with

- **daily mortality**
- **respiratory**
  - **asthma**
  - **lung function etc**
- **cardiovascular**
- **immune function**
- **cancer**



Lots of the evidence for health effects of traffic pollution is "suggestive but not sufficient"

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Health effects

Cardiovascular

CVD – mortality
Increased cardiac events

Subclinical effects – increased susceptibility – sudden fatalities

Fine fraction only (<2.5µm)
no significant effects from coarse fraction (2.5 - 10µm)

Absolute mortality risk from PM higher for cardiovascular than pulmonary – short and long term exposures

UFP
(high surface area)

systemic effects (extrapulmonary)
oxidative stress (→ DNA damage)
Genotoxicity

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The End

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